PLANT AND ANIMAL RESPONSES TO MANAGEMENT STRATEGIES FOR CONTROLLING WEEDS IN PERENNIAL ARACHIS-GRASS PASTURES

By

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Dedicated to the memory of my grandparents Pedro and Luciana Cal-Chin who taught me about what it takes to be a farmer. To my parents and my wife Pearl who provide love, patience, and encouragement when most needed.

To Jasmin, Beverly, Mario, Angelu, and Edward for their love and encouragement.

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PLANT AND ANIMAL RESPONSES TO MANAGEMENT STRATEGIES FOR CONTROLLING WEEDS IN PERENNIAL ARACHIS-GRASS PASTURES

By

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Rhizoma peanut (RPP; Arachis glabrata Benth.)-grass pastures are gaining importance in the southeastern United States. Problems of forb invasion in RPP-grass have been associated with decline of desirable grass components of the sward. Studies were designed to evaluate strategies for increasing competitiveness of desirable grasses and disadvantage weedy forbs [e.g., Mexican-tea (MT); Chenopodium ambrosoides L.]

Changes in botanical composition of RRP-grass pastures in response to (i) N rate (N_0 and N_{35}) and summer-fall stocking rate (1.5 and 2.5 animals ha^{-1}) and (ii) N rate (N_0 and N_{35}) and spring grazing (no grazing or grazing by cattle) were assessed from spring 1995 through spring 1997. In both studies, grass herbage mass (HM) increased with $N_{35,}$ and percentage of grass was further increased when spring grazing was deferred. With all treatments, RPP HM remained essentially the same which resulted in a decline in RPP percentage of total HM.

A second study determined the effects of N rates (N_0 and N_{35}) and summer-fall stocking rates (1.5 and 2.5 animals ha^{-1}) on HM, nutritive value, herbage allowance, and animal performance and diet composition of grazed RPP-grass swards. Most plant and animal responses were not affected by N or stocking rate. Rhizoma peanut percentage in the diet always was greater than in pasture HM; grass percentage in the diet was greater primarily in the spring. Spring average daily gains were 0.20 kg higher than in summer.

A final study evaluated effects of single summer applications of glyphosate (1.12, 2.24, and 3.36 kg ai ha^{-1}) and triclopyr (0.56, 1.12, and 1.68 kg ai ha^{-1}) on DM and botanical composition of weed-infested RPP-grass swards. At the rates tested, triclopyr was more effective than glyphosate in reducing MT DM, but the higher rates of glyphosate and triclopyr decreased RPP DM.

Results from these studies imply that grass proportion of herbage mass in RPP swards can be increased with N_{35}, but this increase may have no immediate effect on weed

encroachment. Applications of glyphosate (2.24 kg ai ha^{-1}) or triclopyr (0.56 kg ai ha^{-1}) will be necessary to reduce weed infestations in RPP-grass swards.

CHAPTER 1
INTRODUCTION

Grassland vegetation consists of several hierarchical levels including the individual plant, the population, and the community which collectively influence pasture productivity and stability (Briske, 1989; Briske and Silvertown, 1993). Pasture systems are highly interactive with environmental conditions and grazing management. These factors affect the rate of growth of pastures and pasture conditions affect animal performance (Hodgkinson and Mott, 1987; Matches, 1989).

Environmental conditions cause seasonal fluctuation in forage dry matter (DM) production and nutritive value particularly in tropical and subtropical environments. In addition, pasture degradation and lack of production stability are common problems throughout the ecosystems of this region. Pastures can be unstable (i.e., change botanical composition rapidly, when management or environmental factors impose stress). Proper management, however, allows pastures to be sustainable (Toledo and Formoso, 1993).

Grazing management tactics are central to improving the proportion of desirable components in pastures (Kemp et al., 1996). Grazing management modifies competitive interactions by influencing frequency, intensity, and seasonality of plant defoliation. Brock and Hay (1993) noted that defoliation frequency and severity interact to produce varying levels of physiological stress and morphological adaptation which affect the survival rate and size of individual growth units (e.g., tiller or stolon). Grazing pressure or stocking rate exerts a dominating influence on animal production per unit area or per head. It also influences forage botanical composition and has a major effect on forage allowance and defoliation and intake of forage by animals. Grazing management, then, is a powerful tool which can be used to influence plant and animal performance in forage-based livestock production systems. Effective use of grazing management, however, requires a proper understanding of plant and animal interactions (Sollenberger and Chambliss, 1989).

`Florigraze' rhizoma perennial peanut (RPP; Arachis glabrata Benth.) is a warm-season forage legume that is adapted to the well-drained, deep, sandy soils of Florida and has been available to producers since 1979 (Prine et al., 1981). Rhizoma perennial peanut pastures have supported yearling cattle gains of 0.75 to 1.0 kg head^{-1} d^{-1}

(Sollenberger et al., 1989; Williams et al., 1989). It has also persisted under continuous stocking (Williams et al., 1989) and over a relatively wide range of rotational stocking practices (Ortega-S. et al., 1992b). Studies conducted by Harrelson et al. (1993) in a mixed RPP-bahiagrass (Paspalum notatum Flügge) sward showed that DM availability was not limiting (pastures were stocked at 1.5 yearling steers ha^{-1}) and ranged from 2100 (March) to 3500 (October) kg ha^{-1}, resulting in excellent animal gains of 0.95 kg d^{-1}. To date, no other forage legume has demonstrated the forage quality, DM production, long-term persistence, and multiple uses that RPP has shown under Florida environmental conditions (French et al., 1994).

The emphasis of RPP research has been on establishment, plant responses to grazing management, and animal performance in nearly pure peanut swards. Most mixtures of existing RPP-grass swards in Florida occur due to failure to control the grass at planting. Perennial grass sods are usually plowed in the fall and disced several times prior to planting RPP, but the grass usually recovers in the summer to make a mixture. These mixtures, however, are often accompanied by weedy forbs (Prine, 1985; Williams, 1994).

Environmental and management conditions clearly impact the competitive balance in RPP-grass-weedy forb swards. Recent pasture botanical composition surveys have documented the problem of weedy forb invasion of RPP swards and have shown a negative correlation between the presence of grass and weedy forbs (Harrelson, 1993). Williams (1994) assessed reasons why bahiagrass may not compete well with RPP. She found limited growth of RPP in the spring to be associated with moisture stress, and noted that rapid growth of RPP did not occur until the start of the summer rains (June-July). In contrast, bahiagrass continues to grow at moisture levels below that at which RPP DM production ceases (Williams, 1994). Lack of other forage sources other than hay or preserved forage for cattle during the spring necessitates early grazing of bahiagrass. This may weaken the bahiagrass and result in its replacement by weedy grasses or forbs. In contrast to what has been observed with bahiagrass, Ortega S. et al. (1992b) observed that common bermudagrass [Cynodon dactylon (L.) Pers.] encroached in RPP swards under close, frequent grazing. This response was similar to that observed by Jones (1979) on a grass-siratro (Macroptilium atropurpureum) mixture where grass contribution increased with higher stocking rates, but the effect of stocking rate lessened as grazing frequency declined. `

Based on data of growth characteristics of RPP and bahiagrass swards and the apparent inhibition of weedy forb invasion when grass is present, Williams (1994) suggested that maintaining a significant grass component in pastures might better suit the requirements of cow-calf producers in Florida. There are several possible management strategies that may enhance grass contribution. Adding N to the system may be necessary because biologically fixed N_2 from RPP was found to be below that needed by an associated grass to remain competitive (Valentim et al., 1986). Valentim et al. (1986) noted that a minimum of 150 kg ha^{-1} of N was necessary to maintain the grass component with multiple harvests for hay. Relative growth rate studies by Williams (1994) suggested that bahiagrass in pastures would need at least 56 kg N ha^{-1} to be competitive with RPP. Time or season of grazing may also be useful as a management tool to improve competitiveness of the grass components in RPP-grass swards. Specifically, resting pastures during the spring drought maybe a useful strategy to favor the grass.

When pasture degradation (loss of valuable species, weed ingress) has continued for a long time it may not be possible to return to a pre-degraded state (Briske and Silvertown, 1993). Jones (1992) noted that in an overgrazed siratro-setaria (Setaria sphacelata) pasture, resting from grazing was unable to cause reversion or restoration of sown grasses. Under such situations the strategic use of herbicides to minimize weed encroachment can be an alternative.

Information regarding the effect of N application, stocking rate, seasonal grazing, and their interactions on vegetation changes and the stability and production of bahiagrass-RPP swards is needed. The interaction of spring N fertilization and increased stocking rate during July to October is unknown. The effects of N rate or stocking rate on weight gains, gain ha^{-1}, body condition, and diet selectivity of growing cattle on RPP-grass swards have not been quantified. Furthermore, the susceptibility and tolerance of RPP-grass pasture to herbicide rates has not been investigated.

For these reasons, a series of field studies were conducted in the spring and summer of 1995 and 1996. The overall objectives of this research were (1) to determine spring N fertilization and summer (July through October) stocking rate effects on the botanical composition, forage DM production, and nutritive value of RPP-bahiagrass swards, (2) to assess changes in botanical composition of newly established RPP-grass swards as affected by spring N fertilization and spring grazing (no grazing or grazing) by cattle, (3) to evaluate spring N-fertilization and summer stocking rate effects on daily gain, gain ha^{-1}, body condition, and diet botanical composition of growing cattle grazing RPP-grass pastures during April through October, and (4) to examine the effect of herbicide treatments (glyphosate or triclopyr) on yield and botanical composition of RPP-grass swards managed for hay.

CHAPTER 2
LITERATURE REVIEW

Importance of Grass-Legume Mixtures in Livestock Systems

Livestock production in tropical and subtropical regions of the Americas is largely based on the use of native and introduced forages. Productivity of forage-livestock systems in warm climates, however, is limited by seasonal forage availability, low production and growth potential of native species, poor persistence of some introduced plants, minimal legume contribution, and low forage quality (Mott, 1981; Ortega-S. et al., 1992a).

Legumes play a key role in the nutrition of grazing animals and contribute variable amounts of N to the associated grass species (Cameron et al., 1993; Thomas, 1992). Long-term studies conducted by Lascano and Estrada (1989) demonstrated an important contribution of tropical legumes to the animal's diet during dry periods. They indicated that high and sustainable liveweight gains can be obtained with legume-based pastures. Grass-legume combinations nearly always have higher animal production in terms of per head performance, increased pasture carrying capacity, and slower rate of decline in forage quality when compared to unfertilized grass pastures (Reed, 1981; Crowder, 1985). Productive legumes can increase the quality and quantity of mixed grasses to a level obtained with moderate N fertilization (Whitney, 1981; Mannetje and Jones, 1990). Thomas (1992) noted that when 25 to 40% of the pasture DM is composed of legumes, pasture N needs could be met and production sustained.

Legumes can improve the quality of the diet of ruminants by increasing the protein concentration of grasses grown in association with the legume, by increasing the intake of energy and protein by animals, and by increasing the length of time that green forage is available to the animals (Jones et al., 1967). Superior growth rates of cattle grazing legume-based pastures have been attributed to higher protein concentration of legumes and lower rate of protein breakdown in the rumen, which combine to produce a greater flow of nonammonia N to the small intestine than for grasses grazed alone (Beever et al., 1985).

Well-managed grass-legume pastures can contribute substantially to year-round grazing systems. In intensively managed pastures, the ceiling for animal production from grass-legume mixtures is determined by the legume and grass proportion and the N-fixing capacity of the legume (Thomas, 1992). However, problems of competition, poor persistence, and pasture degradation as well as inadequate grazing management limit the potential of tropical legumes to supply Nitrogen.

Pasture degradation (loss of important species, weed ingress) occurs when the level of disturbance is too high for desirable plants to tolerate the stress (McIvor, 1993). Noy Meir and Walker (1986) observed an increase in the ratio of unpalatable to palatable species in plant communities as the severity of grazing increased. Weed invasion, the colonization by an adapted plant due to stress or disturbance, is a major problem in grazed pastures. For intensively managed systems, herbicides can be used for weed control (McIvor, 1993). He noted, however, that this is impractical for many pasture situations and suggested as an alternative the changing of pasture conditions to disadvantage the weeds. Weed invasion was noted to be greater where there was less competition, and it was suggested that the use of competitive species can be an adequate control measure if combined with other management practices.

The present review will focus on management strategies (e.g., grazing pressure or stocking rates, N application, timing or season of grazing, and strategic use of herbicides) to modify the botanical composition of grass-legume mixtures and the influence of these strategies on plant and animal responses. The time lag for botanical changes in pastures are long term. Jones et al. (1995) consider that some botanical changes can take place within 2-5 yrs, many changes take place over 5-10 yrs, and some after 10 yrs.

Managing Botanical Composition of Grass-Legume Pastures

The main goal of pasture management is to ensure long-term animal productivity by maintaining stability of the pasture system (Tergas, 1993). Effective management of pastures requires integration of soil and other environmental components (light, temperature, and moisture) with appropriate forage and animal species and grazing methods to achieve specific results and goals (FGTC, 1992). Understanding pasture systems requires knowledge of grazing effects on the dynamics of plant populations, species differences in morphology and physiology which affect persistence and vigor, changes in the plant environment caused by grazing, and the effect of animal selectivity on grazing intensity of the components of grass-legume mixtures (Haynes, 1980; Hodgkinson and Mott, 1987). Haynes (1980) noted that differences in seasonal growth may minimize competition for environmental factors and therefore confer greater degree of stability on a mixture.

Maintenance of the botanical composition of legume-based pastures requires knowledge of the growth rhythm of the sward and the varying response of its components to defoliation by animals using the pasture (Skerman et al., 1988; Gomide, 1989). The botanical composition of a sward is controlled by grazing and/or cutting when these affect (i) the processes involved in individual plant persistence and replacement and (ii) the capacity of the plants to interfere with the availability of environmental growth factors to their neighbors (Humphreys, 1991). Competition between pasture plants for water, light, and nutrients, and the effect of temperature, fire, and flooding, as well as selective grazing affect the day-to-day and seasonal dominance of the component species. Grass and legume mixtures, then, require more careful management than is needed for grass pastures (Mott, 1981).

Grazing Pressure and Stocking Rates

Grazing management and defoliation practices are powerful determinants of growth, persistence, and composition of pastures. Mott (1983) indicated that, with respect to grazing management alternatives, there are three primary components. These are length of grazing period, length of rest period, and grazing intensity. Two main variables in grazing management are grazing intensity (i.e., stocking rate) and grazing method (rotational vs. continuous stocking). Bransby (1989) noted that stocking rate is one of the most powerful driving forces in grazing ecosystems, but its influence on animal production is mediated through effects on sward state and associated effects on quantity and quality of forage consumed by animals. Fales et al. (1995) noted that stocking rates influence the production per ha by determining the proportion of the pasture that the animals consume.

Stocking rate is expressed as the relationship between the number of animals and the grazing management unit utilized over a period of time. Grazing pressure is the relationship between the number of animal units or forage intake units and the weight of forage DM per unit area at one point in time; an animal-forage relationship (FGTC, 1992). Stocking rate and grazing pressure can be managed to optimize intake and forage utilization to ensure the growth of the grazing animal.

According to Tergas (1987), stocking rate influences persistence and utilization of pastures. He indicated that there is a strong interaction between the availability of forage and intensity of defoliation on one hand and intake by the grazing animal on the other. Sollenberger and

Chambliss (1989) indicated that grazing intensity and grazing frequency are important tools in grazing management. They suggested that grazing intensity determines the extent to which plants will be dependent upon energy reserves for regrowth after grazing, and frequency determines if plants have sufficient time to regenerate leaf area and replenish reserves before the next grazing event.

Selection of stocking rates in pasture research is based on some knowledge about the availability of forage throughout the growing season. The number of experimental animals are either fixed (fixed stocking rate experiments) or adjusted according to forage growth (variable stocking rate experiments). Crowder and Chedda (1982) noted that the breadth of the range of stocking rates tested, the number of environments used, and the duration of the grazing trials are important factors to consider in designing grazing experiments.

Increasing stocking rate or grazing pressure results in a decrease in output per animal but an increase in production per hectare, up to a critical point. When high stocking rates are reached, a rapid decline in output per hectare results (Mott, 1960; Crowder 1985). According to Mott (1960) and Mott and Moore (1985) optimum grazing pressure must be considered as an optimum range instead of a "critical point", and such an optimum may relate only to animal output and may or may not be the optimum for plant species in pastures. He suggested the use of variable stocking rates, sometimes called "put-and-take" in grazing experiments to maintain the number of animals in equilibrium with the available forage.

Spain et al. (1985) suggested a flexible grazing management approach for grass-legume associations where stocking rate is adjusted when grazing pressure reaches selected limits, and grazing frequency is adjusted when legume proportion reaches selected limits. Assuming that gain per animal responds linearly to stocking rate, Morley (1978) suggested that the experimental estimation of an optimum stocking rate may be most efficient if only two levels of a fixed stocking rate are compared. He suggested that the lower of these might be some 10 to 20% below a presumed optimum, the higher some 10 to 20% above that level, and that this should permit the maximum efficiency of estimation of a linear response about the optimum.

Jones and Sandland (1974) suggested that the relation between production per animal and stocking rate remains linear over a wide range of stocking rates and likewise suggested that two rates of stocking (with replication) may be adequate for grazing experiments and these would not have to span the optimum stocking rate in order to predict gain at the optimum stocking rate. Bransby et al. (1988)

indicated that financial and logistical constraints usually force a compromise between number of treatments and replications in grazing studies. He recommended using several (more than two) unreplicated grazing levels (stocking rates or herbage allowance) per treatment and using deviation from regression as the error term for testing the stocking rate effect.

Many studies have demonstrated that neither gain per animal nor gain per hectare responds linearly to stocking rate (Sollenberger and Cherney, 1995). Thus, most scientists recommend that grazing studies with fixed stocking rates should include three or more levels. Further, the method recommended by Bransby et al. (1988) requires homogenous pastures. If pastures are not uniform, stocking rate will be confounded with pasture condition and the animal data rendered uninterpretable (Sollenberger and Cherney, 1995).

Grazing Pressure Effects on Grass-Legume Mixtures

A review by Tergas (1993) suggested that the linear relationship proposed by Jones and Sandland (1974) is achieved in most grass-legume studies. He noted that this relationship is especially applicable for grass-legume mixtures where legumes have the most influence on animal productivity and are more severely affected by an increase in stocking rate.

Decreasing contribution of the legumes with an increase in stocking rate has been reported by Clements (1989) and Cameron et al. (1989). Jones (1979) indicated that siratro persistence and productivity are adversely affected by excessive stocking rates. High stocking rates in a siratro-setaria pasture depressed the survival, seed set, and seedling recruitments of siratro plants. Coates and Mannetje (1990) found no differences in cow/calf performance between sown pasture of rhodesgrass (Chloris gayana), green panic (Panicum maximum var. trichoglume) and siratro at high and low stocking rate. Productivity per unit area of sown pasture at 0.68 cows ha^{-1} was over five times that of native pasture due mainly to the effect of the higher stocking rate. Fales et al. (1995) showed that higher stocking rate had a positive effect on pasture nutritive value but had a negative relationship with the percentage of the pasture rejected by cows. They noted that the positive effect on nutritive value was due to a more complete removal of leaf tissue at high grazing pressure. Also a higher proportion of young tillers was observed at onset of each subsequent grazing cycle at high stocking rate compared to low stocking rate.

Bryan and Evans (1973) found that stocking rate had a marked effect on botanical composition of grass-legume pastures. Light stocking (1.23 animal ha^{-1}) favored Paspalum commersonii, Digitaria erianthra, and Desmodium intortum and D. uncinatum over high stocking. At high stocking (2.47 animal ha^{-1}) P. dilatatum, Trifolium repens, and Lotononis bainesii were more prominent than low stocking, but the pastures had more weeds in general. Similar results were reported by Eng et al. (1978).

The impact of grazing pressure on plant population dynamics of speargrass (Heteropogon contortus) oversown with Stylosanthes scabra cv. Seca was evaluated in a subtropical environment (Orr and Paton, 1993). Basal area of speargrass was highest at low stocking and declined linearly with increasing stocking rates resulting in an increase in the legume population. Both seedling recruitment and the size of germinable seedbank of speargrass were higher with a light stocking rate, suggesting that a light grazing pressure would favor the grass.

Fisher and Thomas (1989) monitored associations of Brachiaria spp. in combination with the legumes A. pintoi and Desmodium ovalifolium. Pastures were rotationally stocked and growth rates were determined. They found that the net assimilation rate (NAR) and photosynthetic efficiency of legume leaves were lower than for the grasses, which reflected the different photosynthetic pathways of the C_3 legume and C_4 grasses. They also indicated that NAR for both grasses and legumes was lower when forage allowance was higher, and they attributed these responses to differences in mean leaf age. They suggested that in order to achieve optimum performance of pastures, a balance should be established between animal intake and the amount of leaf material remaining after grazing.

Studies conducted by Santillan (1983) with legume-grass combinations of glycine (*Neonotonia wightii* cv. Tinaroo), *Centrosema pubescens* Benth., guineagrass, and *Pennisetum purpureum* found that legume yields and proportions were highly sensitive to length of rest periods and less sensitive to grazing pressure. He also indicated that short rest periods favored the legumes when growing in association with a tall-growing bunch grass.

Nitrogen Fertilization of Grass-Legume Associations

Grassland productivity is highly dependent on N nutrition. The N necessary for grassland ecosystems is derived from soil organic matter, atmospheric N_2 (symbiotic fixation), or fertilizer N (Lazenby, 1981; Ruz-Jerez et al., 1993). Considerable differences exist among legumes in the proportion of fixed N transferred to the soil and to a companion grass. A review by Haynes (1980) indicated that the amount of N transferred by legumes to associated grasses varies with species of legume, species of grass, age of the sward, and type of management imposed on the mixtures. Seasonal variation in N fixation per unit legume growth has also been observed (Hoglund and Brock, 1978). The level of N input, however, needs to be related to the botanical composition (percentage legume in the sward) and prevailing environmental conditions (Dear and Virgona, 1996).

Competition for available soil N is considered a major determinant of the balance between grasses and legumes in mixtures. Collins et al. (1996) noted that this process occurs both directly, through contrasting effects of N on grass and legume growth, and indirectly, through the consequent repercussions on above-and below-ground interactions. West and Mallarino (1996) indicated that some grass presence is necessary to scavenge soil N and keep N_2 fixation rates high in the associated legume; however, difficulty arises in managing pastures for legume-grass balance.

Mallarino et al. (1990) and Farnhan and George (1994) found nonsignificant or negative relationships between legume proportion and amount of N transfer to an associated grass. Both attributed the lack of a positive relationship to the decreasing yields of the grass component of the mixture as the legume component attained higher yields. The reduction in grass component of the mixture at high legume proportion would result in more residual N available for legume uptake.

Several studies have indicated that grasses grown in association with forage legumes exhibit N deficiency (Cowans and Stobbs, 1976; Valentim et al., 1986; Mallarino and Wedin, 1990; Hoveland and Richardson, 1992; Ruz-Jerez et al., 1993). Steele and Vallis (1988) found that in mixed white clover (Trifolium repens L.)-ryegrass (Lolium perenne) pastures, grass growth was limited by low soil N availability. Nitrogen fertilizer can provide a short-term boost to the soil mineral N pool with associated effects on growth of legume and grasses and N fixation (Crush and Lowther, 1985).

The strategic use of N in legume-grass swards, as a means of increasing the grass proportion has been advocated by many authors (e.g., Brockman and Wolton, 1963; Jones, 1970; Frame, 1973; Nuttall et al., 1980; Reed, 1981; Frame and Boyd, 1987; Mallarino and Wedin, 1990; Hoveland and Richardson, 1992; Williams, 1994; Wilman and Fisher, 1996). Nitrogen fertilization, however, can result in a reduction in N_2 fixation and legume proportion in the swards (Evans, 1979; Ledgard and Steele, 1992; Ledgard et al., 1996).

Cowans and Stobbs (1976) showed an increase in pasture yield with the application of N when stocking rate was high, but no increase at a lower stocking rate on mixtures of green panic and glycine. Wolton and Brockman (1970) studied N applications (0-135 kg ha^{-1}) on grass-white clover and found that mixed swards yielded more than unfertilized grass swards. Nitrogen applications rates of 0, 45, 90, 135, and 180 kg ha^{-1} on bromegrass (Bromus inernis L.) and alfalfa (Medicago sativa L.) were evaluated by Nuttal et al. (1980). Percentage of alfalfa in the sward was significantly reduced by as much as 30% with increasing rates of N. Brown and Byrd (1990) applied 100 kg N ha^{-1} on mixtures of alfalfa and bermudagrass and reported yields of 10 Mg ha^{-1} for the mixture, similar to yields of bermudagrass fertilized with 200 kg N ha^{-1}. Hoveland and Richardson (1992) indicated that birdsfoot trefoil did not fix sufficient N for cool-season growth of tall fescue and that applications of N in February and again in September extended the productive seasons of tall fescue-birdsfoot trefoil mixtures. Wilman and Fisher (1996) studied two rates of N (0 and 66 kg ha^{-1}) on a perennial ryegrass-white clover sward and found that applied N increased the number of ryegrass tillers, and this favored the grass competition with the clover. Ledgard et al. (1995) evaluated nine cultivars of white clover in association with perennial ryegrass fertilized with N rates of 0 or 390 kg ha^{-1}. They reported that although pasture production increased (25-31%), white clover production decreased as a result of N application by 8, 17, and 30% in Years 1, 2, and 3, respectively. Fertilizer N decreased annual N_2 fixation from 111 to 47 kg N ha^{-1} (Ledgard et al., 1996). Lowe et al. (1992) used applications of glyphosate, N, S, and oversowing to improve degraded kikuyu (Pennisetum clandestinum)-white clover pastures. Fertilizer and increased stocking pressure without herbicide increased DM of all grasses, but did not control the spread of unpalatable grasses.

Jones (1970) studied the effect of N fertilizer applied in the spring and autumn on yield and botanical composition of rhodesgrass (Chloris gayana)-siratro, and setaria-siratro mixtures. In the first year, 112 kg N ha^{-1} had little effect on siratro yield, but there was a marked reduction at a higher rate of 336 kg N ha^{-1}. His results suggest that an application of 112 kg N ha^{-1} can be used strategically to increase grass yield in a system in which different pastures are fertilized each successive year at a time when the legume is producing little growth.

Grazing Methods

In much of the tropics and subtropics, forage DM production occurs primarily in a defined rainy season, thus requiring adjustments in grazing management systems if forage is to be distributed over an entire year (Crowder and Chedda, 1982).

Grazing methods have been described as "specific defined procedures or techniques of grazing management to achieve specific objectives" (FGTC, 1992). Two common grazing methods include continuous and rotational stocking. Continuous stocking is defined by FGTC (1992) as "a method of grazing livestock on a specific unit of land where animals have unrestricted and uninterrupted access throughout the time period when grazing is allowed", and rotational stocking is defined as "a grazing method which utilizes recurring periods of grazing and rest among two or more paddocks in a grazing management unit throughout the period when grazing is allowed". The terms grazing cycle (the total number of days elapsing from the beginning of one grazing period in a particular area until the beginning of the next period), grazing period (the average number of days within a cycle during which each paddock is occupied by grazing animals), and rest period (the number of days within a cycle when there are no livestock in a particular paddock) are commonly used in rotational stocking systems (Holmes, 1989).

Controversy exists as to whether continuous or rotational stocking is superior in terms of animal and pasture performance. Continuous stocking is more prevalent in extensive conditions where stocking rate in relation to pasture production is low. Crowder (1985) noted, however, that this method commonly favors production per head during the season of active plant growth because of selective grazing, but it may also result in spot grazing. In contrast, rotational stocking is suited to intensive utilization of improved pastures and is designed to obtain more uniform grazing than the continuous system. Tergas (1987) indicated that under intensive grazing of grass-legume associations, better results are expected under a rotational system because it allows the regeneration of stands by accumulation of carbohydrate reserves.

Seasonal and Stocking Effects on Grass-Legume Mixtures

Most of the research on grass-legume mixtures has been conducted under continuous stocking, and it was suggested that the advantages of rotational stocking might appear only with high stocking rates (Tergas, 1993). Stobbs (1969) and Walton et al. (1981) compared continuous and rotational stocking of grass-legume mixtures in a tropical and temperate environment, respectively, and both found little difference in short term effects on animal production due to grazing method. In the Australian humid tropics, Grof and Harding (1970) found greater animal production in a system of alternate grazing (2 wk on and 2 wk off) than continuous stocking of two pastures of guineagrass-*centrosema* mixtures with high stocking rates. Continuous and rotational stocking on buffelgrass (*Cenchrus ciliaris*) and siratro pastures also gave similar liveweight gains (Mannetje and Jones, 1990). Results from Stobbs (1969) showed, however, that after 3 yr of continuous stocking on guineagrass and Siratro mixtures, the guineagrass proportion in the pasture was drastically reduced. Lascano (1987) reported that pastures continuously stocked had more weeds than rotationally stocked and indicated that in the long run, it is likely that animal production would be greater in the more stable pastures under rotational stocking. Fisher and Thomas (1989) monitored an association of *A*. *pintoi* with species of *Brachiaria* under rotational stocking to determine differences in controlled growth during the rest period. They indicated that residual leaf material was the primary determinant of regrowth capacity of the legume. This has also been confirmed by Ortega-S. et al. (1992a) with grazing of RPP. They indicated that very close grazing with short regrowth intervals should be avoided if productivity is to be sustained.

Edye et al. (1978) examined seasonal relationships between animal gains, pasture yield, and stocking rate on continuously stocked guineagrass-*stylosanthes* or guineagrass-siratro. They found that on an annual basis there was no effect of stocking rate, but on a seasonal basis there were significant effects in all seasons. In the dry season, animal gains increased as stocking rate decreased, but in the wet season gains fell with lower stocking rates. A major problem in pasture management in the humid tropics is to control excessive pasture growth in the wet season Edye et al. (1978). These results suggest that some grass-legume pastures in the humid tropics may be commonly understocked, and this results in a reduction in pasture nutritive value, percentage utilization, and animal performance. Kemp and Dowling (1993) noted that pasture composition can be improved, within climatic constraints, by strategic seasonal grazing. They indicated that clover-phalaris (Phalaris aquatica) pastures can be optimized by continuous stocking over the summer and autumn followed by long rotation during the winter, and maintaining the pasture short either by continuous or rotational stocking in the spring. Long rest periods between grazing were found to reduce the content of relatively prostrate plants such as subterranean clover (Trifolium subterraneum) in grass-legume pastures (Snaydon, 1987), and favor perennial grasses, whereas increasing grazing pressure may have the opposite effect (Kemp et al., 1996). Management strategies which combine stocking rate with grazing method are more likely to lead to a more rapid change in composition of introduced or planted pastures as these are more unstable and sensitive to changes than a complex native pasture (Snaydon, 1987).

Grazing management strategies need to be developed with clear objectives. Evans (1982) considers that the benefits derived from rotational stocking are more related to the balance of species that make up the pasture than to the increase in nutritive value of the forage or to animal production. Pasture management, then, should be viewed not only in terms of individual animal performance but also in terms of animal production per hectare and pasture stability.

Selection of Legumes by Livestock

Grazing animals are highly selective of the plant part or forage species that they eat. In grass-legume mixtures, the legume proportion in the diet of the grazing animal is related to (i) the proportion of legume in the sward, (ii) the relative distribution of the morphological components of grasses and legumes, and (iii) the herbage mass, height, and density of the pasture (Lascano, 1987).

Sollenberger et al. (1987) determined the relationships between canopy botanical composition and diet selection by cattle in aeschynomene (_Aeschynomene_ _americana_) and limpograss (_Hemarthria_ _altissima_) pastures. Cattle selected for legume early in a grazing period, but differences between diet and canopy decreased as the proportion of the legume in the canopy decreased. As the canopy was grazed down, total herbage bulk density of the surface layer increased and legume leaf to stem ratio decreased resulting in a reduction in legume selection. Lascano and Thomas (1988) measured selection of A. pintoi when it was grown in association with four species of Brachiaria and found that the legume content in the forage on offer was high but varied, 28% during the dry season and 58% in the wet season. Corresponding values in diet selected were 37% and 60%, indicating that animals selected legume in a slightly higher proportion than was present in the total forage on offer.

A seasonal pattern of legume selection by grazing animals has also been observed for tropical legumes. Several studies conducted in Australia and Colombia indicated preference for and selection of the legumes Stylosanthes humilis, S. capitata, and Pueraria phaseoloides during the dry season. In contrast, selection of A. pintoi was highest in the wet season. Lascano and Thomas (1988) found that there was no active selection against A. pintoi regardless of availability level in the pasture. They attributed the high selection of A. pintoi during the rainy season to high palatability, the type of sward canopy structure, and to the relatively high legume content in the pasture. Harrelson et al. (1993) found that RPP appeared to be preferentially selected during the month of July, a rainy month in Florida, but that grass was selected in April.

Lascano (1987) noted that with bunch-type grasses, animals can be highly selective with clear preference for the legume in the dry season, which is not the case with legumes in association with stoloniferous grasses. Gardener and Ash (1994) observed that the proportion of the legume stylosanthes in the diet was greatest in the dry season and least in the wet season, when grass was preferred. Legume selection for both studies were derived using esophageally-fistulated animals, a technique which at times has given unreliable estimates of diet composition (Coates et al., 1987; Jones and Lascano, 1992). The effect of year, season, and botanical composition on dietary preference of cattle grazing stylosanthes-grass pastures was examined by Coates (1996) using fecal carbon ratios. Cattle showed preference for grass in the early wet season and in late dry season. The proportion of stylosanthes in the diet increased during the wet season and reached proportions as high as 80% in the late wet or early dry season. On an annual basis stylosanthes accounted for 45% of the diet which was appreciably higher than the proportion of stylosanthes in the pasture. The effect of botanical composition on dietary legume proportions varied between and within years, but correlations between grass-legume proportions in the pasture and in the diet were highest in the late dry and early wet season when preference for grass was strongest.

Understanding the effect of plant structure and the relationship between legume proportion in the diet of grazing animals and in the available forage, is important in the development of grass-legume grazing management programs.

Methods for Determining Diet Selectivity

Knowledge of the botanical composition of herbage consumed by grazing animals is essential in understanding animal performance and improving pasture and animal management techniques (Forwood et al., 1987). Several techniques have been devised for evaluating diet botanical composition of grazing livestock. These include visual observations of the diet selected by the animal, ruminal content analysis, extrusa from esophageally fistulated animals, fecal carbon ratios, and microhistological analysis of fecal material (Spark and Malechek, 1968; Williams, 1989; Mohammad et al., 1995).

Accuracy and precision are problems with direct observations, and fistulation is costly (surgery and maintenance of the fistulated animal). Microhistological analysis relies on the identification of epidermal fragments of plants in fecal samples to determine diet botanical composition. Sampling error and observer bias in microhistological identification of epidermal fragments are major criticisms of this technique. In addition more digestible material can be underestimated due to overfragmentation and complete digestion (Williams, 1989). Van Soest (1975) and Bartolomé et al. (1995), however, have addressed the theory that the digestion process has little effect on the epidermis of perennial plants (structural volume is not affected by digestion).

Specialized training in plant fragment identification is key to improving the accuracy of the microhistological technique. A comparison of fecal analysis and the extrusa method by Vavra et al. (1978) found a low correlation between the two methods, but noted that the ranking of the individual species was similar. Fecal analysis can give an accurate assessment of percent diet botanical composition of grazing livestock and can also be used to rank the relative importance of forage species.

Herbicides

Traditional approaches of resowing, use of fertilizer, and herbicides can be used to revert degraded pastures to a productive state (Kemp et al., 1996), but renovating degraded pastures by resowing is very costly. Herbicide use in degraded pastures was suggested as an option for manipulating pasture composition (Simpson and Langford, 1996). The use of herbicides for manipulating pasture composition requires that the undesirable species be considered. Unpalatable woody shrubs or spiny or toxic plants require mechanical or chemical treatments to reduce their incidence or encroachment (Kemp et al., 1996).

The long term benefits of using herbicides in pastures have not been proven. Application of glyphosate on kikuyu and white clover was used to improve a degraded pasture (Lowe et al., 1992). Herbicide application was found to reduce the frequency and production of grass weeds. Weeds reinvaded treated areas after 4 yr and periodic retreatment was suggested for long-term control. Tebuthioron was applied at rates of 1.0 and 1.5 kg ai ha^{-1} onto S. scabra-speargrass pastures (Anderson et al., 1993). This herbicide was effective in the control of the woody plant Eucalyptus populnea without deleterious effect on stylosanthes if rates did not exceed 1 kg ai ha^{-1}.

Herbicide tolerance of grass and legume species can give added flexibility when considering management options for improving pastures. Hawton et al. (1990) generated data from field experiments and reported the tolerance of seed crop legumes to several herbicides. For instance, A. pintoi was found to be tolerant to the herbicides acifluorfen, bentazone, fluazifop-butyl, sethoxydim, 2,4-D, and 2,4-DB (ester). Dwyer et al. (1989) reported that established swards of A. pintoi were tolerant to glyphosate (10 ml L^{-1}). Alachlor (1.4 kg ai ha^{-1}) applied pre-emergent showed greater selectivity towards A. pintoi (Argel and Valerio, 1992).

Simpson and Langford (1996) noted that the acid-tolerant grass Microlaena sp. was found to be tolerant of herbicides (e.g., glyphosate at 2 L ha^{-1}). The effect of glyphosate on seedhead development of bentgrass Agrostis castellana was investigated by Hill et al. (1996). Applications of 0.14 and 0.23 kg ai ha^{-1} prevented the formation of seedheads and stimulated renewed vegetative growth in response to summer rains. They suggested that a glyphosate rate of 0.14 kg ai ha^{-1} has the potential for reducing the dominance of bentgrass and creating an opportunity for follow up fertilizer and management techniques to maintain productive pastures.

Rhizoma Perennial Peanut

The genus Arachis is native to South America with most perennial species are distributed from about 8 to 30° S along the Amazon river through Brazil, Bolivia, Paraguay, Uruguay, and close to northern Argentina (Gregory and

Gregory, 1979; Valls et al., 1985). *Arachis glabrata* Benth. was collected from a black soil at Campo Grande, Mato Grosso, Brazil and listed as PI 118457 (Skerman et al., 1988). This plant was characterized as having underground stems (rhizomes). It is a low growing plant with primary branches being prostrate or creeping and often attached to the ground by adventitious roots (Skerman et al., 1988). The leaves of RPP are small, glabrous and four foliate, and flowers yellow and axillary.

Rhizoma perennial peanut was introduced into the United States in 1936 by W. Archer, and subsequently developed into a selection 'Arb' (Prine, 1964). In 1962, a different plant was observed growing between experimental plots of PI 118457 (Prine, 1973). This plant material was isolated and evaluated at the University of Florida as Gainesville selection No. 1 (GS-1) and later released as Florigraze in 1978 (Prine et al., 1981). An introduction from Paraguay in 1959 listed as PI 262817 was evaluated by the Soil Conservation Service Plant Materials Centers in Arcadia and Brooksville, and the University of Florida. In 1985 it was released as cultivar Arbrook (Prine et al., 1986).

Adaptation

Rhizoma perennial peanut is adapted to moderately well to well-drained sandy soils of the humid subtropics and tropical areas. Prine et al., (1986) noted that a pH range of 5.8 to 6.5 is adequate for RPP growth. Rhizomes were observed to spread slowly in heavy clay soils (Niles, 1989), but in well-drained sandy soils, they spread rapidly. This legume is also adapted to high rainfall conditions and grows rapidly in warm, moist periods of the year. It can survive low temperatures (-16° C), because of its dense rhizome system which extends 10 to 20 cm below the soil surface, and can tolerate drought conditions (Prine et al., 1981; Prine et al., 1986; Dunavin, 1992).

The major factors limiting widespread use of RPP cultivars Florigraze or Arbook as perennial forage crops are their low seed production, which necessitates that they be propagated vegetatively by means of rhizomes, and their slow rate of establishment.

Establishment

Planting of RPP is accomplished by vegetative propagation using rhizomes. Rhizoma perennial peanut is slow to obtain complete ground cover after emergence and a full cover can take as long as 3 yr (Prine et al., 1986). Williams et al. (1997) noted that rate of coverage is thought to be related to the number of RPP sprouts per unit area that survive from emergence up to 12 wk, and this has led to an increase in the recommended minimal planting rates of 630 to 1260 kg rhizomes ha^{-1}. Planting rates are dependent on cost of purchasing rhizomes. One ha of a well-established RPP pasture can be used to plant approximately 20 ha (M.J. Williams, 1997, personal communication).

A recent study by Rice et al. (1995) indicated that the chemical composition of the rhizomes is a major determinant in rate and overall success of RPP establishment, especially in years with average or below average spring rainfall. It was recommended that rhizome total nonstructural carbohydrate (TNC) concentration of planting material exceed 200 g kg^{-1} to minimize the risk of stand failure. Other studies indicate that rhizomes low in vigor may be susceptible to decay and drought, and the weak shoots produced may be very poor competitors with weeds (Niles, 1989; Canudas et al., 1989).

In Florida, RPP is planted in the winter (January to March) when top growth is absent, rhizomes are dormant (Prine et al., 1986), and TNC levels are high (Saldivar et al., 1992). Drought conditions during this period result in poor sprout survival. Williams (1993) observed that winter plantings had over 50 sprouts m^2 at 2- to 4-wk post planting, but drought conditions in April and May resulted in 90% sprout loss. Summer plantings (July) had lower sprout emergence (approximately 30 sprouts m^2), but sprout survival was higher than winter plantings (56.9% vs. 41.2%).

A recent study (Williams et al., 1997) found that rate of RPP plant cover is highly variable, taking between 52- and ≥104-wk post planting to reach ≥60% cover. On average, February plantings achieved ≥60% ground cover at 52-wk compared to 78-wk for April, 78-wk for June, 104-wk for August, and 104-wk for December. They suggested that soil moisture (rainfall or irrigation) 60 to 90 d post planting is critical for sprout survival and RPP cover. Establishment of RPP is also improved by reducing weed competition. Canudas et al. (1989) found that first-year cover of Florigraze doubled when both grass and broadleaf weeds were controlled.

Due to slow rate of plant spread, Prine (1973) suggested the use of companion crops along with newly planted RPP to make the establishment period profitable. Interplanting 'Florida 77' alfalfa with RPP was evaluated by Valentim et al. (1987). They observed that the alfalfa DM dominated the sward for the first 2 yr, but as alfalfa yield declined, it was replaced by RPP by the fourth year.

Dry Matter Yield and Quality of Rhizoma Perennial Peanut

Prine (1973) noted that DM production is affected by moisture conditions, fertilization, and light. Beltranena et al. (1981) and Ocumpaugh (1990) reported total DM yields between 6 and 12 t ha^{-1} from numerous clipping studies, and

DM yields of 8.8 t ha^{-1} in pure stands were cited by Valentim et al. (1988). Romero et al. (1987) reported that DM of RPP increased as cutting interval lengthened, 3 t ha^{-1} when cut every 6 wk to more than 8 t ha^{-1} when cut at 12-wk intervals. Current recommendations for hay production in Florida are to cut well-established RPP stands three times a year corresponding to 8-wk cutting intervals starting in early to mid-June. Harvesting at a 12-wk interval (2 cuts per year) results in similar hay yields but lower nutritive value (Prine et al., 1986).

The nutritive value of RPP is similar to alfalfa, with whole plant CP between 120 and 180 g kg^{-1} and digestibility between 600 and 750 g kg^{-1} (Williams et al., 1991). Prine et al. (1986) reported nutritive values of Arbrook, Florigraze, and _A_. _benthamii_, averaged across years of 139, 150, and 154 g kg^{-1} CP, respectively, and in vitro organic matter digestibility (IVOMD) of 653, 648, and 589 g kg^{-1}, respectively. Generally, the CP and digestibility of RPP are higher than the mean values of 169 g kg^{-1} CP and 566 g kg^{-1} In vitro dry matter digestibility for a large sample of tropical legumes reported by Minson and Wilson (1980) and Minson (1984).

Excellent weight gains have been reported for animals grazing _Arachis_ spp.: 627 kg ha^{-1} annum^{-1} (0.5 kg d^{-1}) on _A_. _pintoi_ (Grof 1985) and average daily gains of 0.75 to 1.0 kg

d^{-1} on RPP pastures (Kunkle et al., 1988; Williams et al., 1989; Sollenberger et al., 1989; Harrelson, 1993). This demonstrates that Arachis is an excellent source of protein and energy for grazing animals.

Grazing Management of Rhizoma Perennial Peanut

Studies by Ortega-S. et al. (1992b) found that RPP is productive and persistent under a wide range of management practices. They noted, however, that very close grazing, and short regrowth intervals should be avoided if productivity of RPP is to be sustained. In addition, when they examined rhizome characteristics and canopy light interception of RPP under grazing, they found that residual leaf area was primarily responsible for regrowth under lenient grazing, but rhizome reserves were most important when pastures were grazed closely and frequently.

Grazing information on mixed grass-RPP swards is limited. Williams et al. (1991) investigated the productivity of a mixed grass-RPP pasture under continuous stocking. They observed that RPP was responsible for most of the increase in DM compared to bahiagrass in the sward. Further studies by Williams (1994) noted that, under grazing, the grass component of a mixed bahiagrass-RPP sward appears to decline. She suggested that the reduction of bahiagrass growing with RPP may be due to competition for soil moisture or for light at the critical spring stage of growth. Also it is possible that bahiagrass suffered from potentially increased grazing stress because the grass continued to grow and be defoliated when RPP was dormant during periods of low soil moisture. *Arachis pintoi* has persisted well under grazing and dominated associations of *Brachiaria*, similar to the dominance found with RPP in bahiagrass pastures (Grof, 1985).

Bahiagrass

Bahiagrass, a native of South America, is widely distributed in Argentina, Paraguay, Brazil, Central America and the West Indies (Burson and Watson, 1995). This grass is a deep-rooted, sod-forming perennial that grows by adding new phytomers to tillers located at the terminal end of vegetative stolons (Sampaio and Beaty, 1976). Burson and Watson (1995), however, referred to these structures as short, stout, often exposed rhizomes which form a dense sod. Bahiagrass has many flat or folded basal leaves, less than 1.2-cm wide, pubescent on the margin, and stiffly spreading.

Bahiagrass was introduced to the southeastern United States as a forage and erosion-control grass in 1913 by the Florida Agricultural Experiment Station (Burson and Watson, 1995) and is currently grown on nearly 2 million ha of land

(Rechcigl et al., 1995). It is the most common introduced pasture grass grown in Florida and is primarily used as the foundation for cow-calf production (Chambliss and Jones, 1981; Chambliss and Sollenberger, 1991).

Since its introduction, several cultivars of bahiagrass have been released. 'Pensacola' is the most commonly grown cultivar in Florida pastures (Chambliss and Jones, 1981). It is taller and more persistent than 'Argentine', has longer and narrower leaves and is more cold tolerant than other released cultivars. Argentine is less cold tolerant than Pensacola and initiates growth later in the spring (Chambliss and Jones, 1981). Other releases include 'Paraguay','Paraguay 22', and most recently 'Tifton 9'.

Adaptation

Bahiagrass is adapted to a wide range of environmental conditions. It grows best on sandy, light-textured soils with pH of 5.5-6.5 (Jones 1971, cited by Burson and Watson, 1995), but can also grow on heavy clay soils (Bodgan, 1977). It also tolerates drought (Henderson and Robinson, 1982) and flooding (Schroeder, 1966) once it is well established. Bogdan (1977) noted that bahiagrass is tolerant to a higher degree of shading than most other tropical grasses.

Establishment

According to Chambliss and Jones (1981) bahiagrass should be planted on a well-prepared seedbed at a depth of 0.6-1.25 cm. Seeding rates of 11-22 kg ha^{-1} (400 seed m^{-2}) are recommended for pasture planting (Burson and Watson, 1995; Gates and Mullahey, 1997). Bahiagrass is generally sown in the early spring. Spring planting may result in a more rapid establishment of a sod if an April or May drought is avoided (Chambliss and Jones, 1981). Temperatures and moisture in the summer are ideal for planting but summer plantings usually have severe weed infestation.

Dry Matter Yield and Quality of Bahiagrass

Nitrogen appears to be the most limiting nutrient for DM production of bahiagrass. Blue (1988) showed a linear increase in DM with increasing rates of fertilizer N. Yield on an Entisol (excessively drained soil) was 1.5 Mg ha^{-1} for (0 N) and 8 Mg ha^{-1} for 200 kg N ha^{-1}. On a Spodosol (poorly drained-flatwood soil) bahiagrass yielded 4 Mg ha^{-1} and 13.2 Mg ha^{-1} for 0 and 200 kg N ha^{-1}, respectively. Cuomo et al. (1996) reported an average yield of 11.5 Mg ha^{-1} for Pensacola, Argentine, and Tifton 9. Sumner et al. (1991) noted increased yield due to application of N in March and that this continued throughout the summer period. The response of N application in September was also immediate but limited only to September or October harvests.

Protein and IVOMD concentrations of bahiagrass are low in July, August, and September, and this adversely affects animal performance (Kalmbacher et al., 1988). Moore et al. (1969) reported that CP concentration of Argentine bahiagrass under continuous stocking decreased from 86 to 58 g kg^{-1} DM during the grazing season (May to September). Williams et al. (1991) also reported a decline in protein concentration as the grazing season progressed (162 to 64 g kg^{-1}; from April to September). In this study, bahiagrass IVOMD also decreased from 630 to 491 g kg^{-1} from April to September. Utley et al. (1974) reported similar effects on IVDMD, which decreased from 680 g kg^{-1} for May samples to 430 g kg^{-1} for September forage samples. Sumner et al. (1991) noted that the CP concentration of bahiagrass regrowth forage increased with increasing rates of N fertilization, but increases were relatively small.

Animal gains on bahiagrass are highest during the spring. Prates et al. (1975) noted that gains can exceed 1 kg d^{-1} in the spring, but losses in weight may occur in the late summer and fall months. Utley et al. (1974) reported steer gains of 0.43 kg d^{-1} on Pensacola bahiagrass. Williams et al. (1991) reported similar gains of 0.51 kg d^{-1}. Rapid growth of bahiagrass in the summer increases the percentage of mature (fibrous) and dead material in the available forage and reduces pasture utilization and quality (Hodges et al., 1976; Sampaio and Beaty, 1976).

Grazing Management of Bahiagrass

Bahiagrass withstands close grazing, overgrazing, infrequent fertilization, and is resistant to weed invasion, which characterize the low levels of pasture management often used in Florida (Kalmbacher et al., 1988; Pitman et al., 1992). Bahiagrass will persist over subsequent growing seasons. The growing points, which are just at or above the soil surface, enable this grass to have sufficient regrowth under grazing or clipping. Beaty et al. (1970) observed that intense clipping and low soil N levels over two growing seasons thinned bahiagrass stands, but reports of low persistence for the grass under poor management are lacking.

The highest potential for utilization of bahiagrass is under adverse subtropical conditions of the southeastern USA that limit the productivity of higher quality grasses. Its adaptation to soils of marginal fertility and its aggressive growth and persistence increases its value as a forage crop (Kalmbacher et al., 1988). Low forage yield and quality of bahiagrass, however, are major limitations. Payne et al. (1990) noted that although N fertilization can increase yield, fertilizing bahiagrass pastures for maximum yield is economically infeasible. In addition, most pastures occur in sandy infertile soils which have little ability to retain nutrients. The typically low yield and low forage quality of bahiagrass provide incentive for development and introduction of forage legumes in these pastures.

CHAPTER 3
MANAGEMENT EFFECTS ON BOTANICAL COMPOSITION OF RHIZOMA PERENNIAL PEANUT-MIXED GRASS ASSOCIATIONS

Introduction

'Florigraze' rhizoma perennial peanut (RPP; *Arachis glabrata* Benth.) is a well-adapted, warm-season forage legume that was released in Florida in 1981 and has been used for hay and grazing. Rhizoma perennial peanut exhibits exceptional persistence (Ortega-S. et al., 1992b) and high nutritive value (Sollenberger et al., 1989; Williams et al., 1991). Most RPP swards are mixtures with warm-season perennial grasses. Grasses are seldom planted with RPP, but mixtures occur due to a failure to control the grass at planting or during RPP establishment.

Invasion of RPP-mixed grass swards by forbs has been observed as stands age (Prine, 1985; Williams, 1994). Williams et al. (1991) reported that encroachment of weeds in RPP-mixed grass swards have not shown any decline in RPP contribution; however, the grass component declines with time and is replaced by weeds [e.g., Mexican tea (MT), *Chenopodium ambrosoides* L.]. Williams (1994) suggested reasons why bahiagrass (Paspalum notatum Flügge) may not persist well with RPP. She found limited growth of RPP in the spring to be associated with moisture stress and noted that rapid growth of RPP did not occur until the start of the summer rains (June to July). In contrast, bahiagrass grows at moisture levels at which RPP DM production ceases. Thus bahiagrass is grazed heavily during the spring dry period. She suggested that the decline of bahiagrass growing with RPP may be due to overgrazing of bahiagrass in spring and competition for light at the start of the summer rainy season when RPP begins rapid growth.

Nitrogen fertilization and or altering grazing pressure may be useful as management tools to improve competitiveness of the grass components in RPP-mixed grass swards and minimize weed encroachment. Valentim et al. (1986) noted that adding N to the system may be necessary because the amount of biologically fixed N_2 from RPP available to an associated grass was below that needed by the grass to remain competitive. They reported that a minimum of 150 kg ha^{-1} of N was necessary to maintain the grass when multiple harvests were made from a grass-RPP sward. Based on relative growth data of N-fertilized and unfertilized bahiagrass, Williams (1994) suggested that bahiagrass would need at least 56 kg N ha^{-1} to remain competitive with RPP. It is likely that grazed swards would require less N than harvested swards because a high proportion of nutrients are returned to the grazed pastures in dung and urine. In addition to N, stocking rate is a key determinant of pasture botanical composition and nutritive value (Evans, 1982). Varying the timing of grazing and stocking rate affects when animals can be selective and when they cannot, thus exerting considerable influence on the botanical composition of the pasture (Kemp et al., 1996).

Little information exists regarding the effect of N application, stocking rate, seasonal grazing, and their interactions on the stability of RPP-mixed grass swards. The objectives of this research were to assess changes in the botanical composition of RPP-mixed grass pastures in response to (i) spring N fertilization of 0 (N_0) and 35 (N_{35}) kg N ha^{-1} and summer-fall (July through October) stocking rates (1.5 and 2.5 animals ha^{-1}) and (ii) spring N fertilization (N_0 and N_{35}) and spring grazing (no grazing or grazing) by cattle.

Materials and Methods

Experiments were conducted at the USDA, ARS, Subtropical Agriculture Research Station, Brooksville, FL (28° 37'N, 82° 22'W). Rhizoma perennial peanut-mixed grass swards were grown on a Candler fine sand (hyperthermic, uncoated, Typic Quartzipsamment) with very low water holding capacity. Soil pH was 5.7, and Mehlich I extractable P and K averaged 104 and 64 mg kg^{-1}, respectively. Spring months are usually dry, and the onset of the summer rains generally occurs in mid-June to early July (Table 3.1). The 30-yr mean annual rainfall at Brooksville is 1,371 mm. Maximum daytime temperatures regularly exceed 32°C in the summer.

Experiment 1

Two adjacent 16-ha, 15-yr-old RPP-mixed grass swards were subdivided to make 8, 4-ha pastures and used for studies in 1995 and 1996. Pastures consisted of a mixed sward of RPP with bahiagrass, bermudagrass [*Cynodon dactylon* (L.) Pers], MT, cogongrass [CG; *Imperata cylindrica* (L.) Beauv], blackberry (*Rubus cuneifolius* Pursh), and several winter annuals. Pastures were fertilized in the spring (14 Mar. 1995, 15 Apr. 1996, and 12 Mar. 1997) with 13 kg P, 50 kg K, and either N_{35} or N_0.

All pastures were stocked at 1.5 animals ha^{-1} from spring (12 Apr. 1995 and 16 May 1996) through early summer (5 July 1995 and 11 July 1996). From the end of the early summer period through the fall (28 Sept. 1995 and 3 Oct. 1996) the stocking rate was increased to 2.5 animals ha^{-1} on half the pastures. Treatments were arranged as a two by two factorial in a randomized block design with two replicates.

Table 3.1. Monthly rainfall in 1995 and 1996 and the 30-yr average at Brooksville, FL.

Month	Year		
	1995	1996	30-yr average
	----------mm----------------		
January	118	124	73
February	58	69	92
March	56	191	107
April	98	90	57
May	78	97	111
June	246	136	169
July	177	52	195
August	360	143	220
September	248	78	166
October	274	67	61
November	23	11	51
December	67	34	69
Total	1803	1092	1371

Six yearling bulls per pasture for the 1.5 animals ha^{-1} rate and 10 head per pasture for the 2.50 animals ha^{-1} rate were continuously stocked on the pastures. Bulls had an average initial weight of 370 kg in April 1995 and 357 kg in 1996. Information on breed groups is provided in Chapter 4.

Sward components were assessed in the spring (April), summer (July), and fall (October) of 1995 and 1996 and spring 1997 using a double sampling technique (Campbell and Arnold, 1973; Ortega-S. et al., 1992b) to determine herbage mass of MT, other forbs, CG, grasses (bahiagrass and common bermudagrass) other than CG (referred to as grasses in the text), and RPP. Double sampling included visual estimates as the indirect measure and hand separation of clipped herbage as the direct measure. Visual estimates were made and herbage was clipped to a 2.5-cm stubble height at five 0.25 m^2 quadrats in each pasture. Hand-separated samples were dried at 60°C for 48 h and actual component mass (kg ha^{-1}) was determined. Additionally, visual estimates of MT, CG, other forbs, grasses, and RPP, were taken at 15 randomly selected locations in each pasture. Actual values of herbage mass for the components were regressed on visual estimations of the responses from the double sampling sites to generate prediction equations. Means of the 15 visual estimations from each pasture and the prediction equations generated from double sampling were used to predict component herbage mass. Percentages of MT, other forbs, CG, grasses, and RPP in total herbage mass were calculated by summing mass of all components and dividing mass of each component by this total. Equations developed for spring, summer, and fall seasons of 1995 and 1996 and spring season of 1997 were used for MT and grasses (Table 3.2). Year-long equations across seasons (Table 3.3) were used for CG, other forbs, and RPP because the equations for each season had similar r^2, standard errors of the estimate, slopes, and intercepts.

The response variables tested were component herbage mass, percentages of each component in total herbage mass, change in percentage of each component from 1995 to 1996 (average across seasons within year), and change in percentage of each component from spring 1995 to spring 1997. Repeated measures analysis of variance procedures were used to test the effects of treatment and sampling dates on percentage of each component. Statistics were based on the univariate approach, assuming first-order autoregressive correlation among the repeated measures, and were conducted using the PROC MIXED procedure of SAS (Littel et al., 1996). Changes in percentage of each component from 1995 to 1996 and from spring 1995 to spring 1997 were analyzed as a randomized block design using PROC GLM of SAS (1989). Sources of variation were N rate, stocking rate,

Table 3.2. Regression equations from double sampling that were used to predict herbage mass from visual estimates of Mexican tea (MT) and grass herbage mass (kg ha^{-1}).

Plant Fraction	Season	1995	1996	1997
MT	Spring	y†=93+0.7x‡ SEyE¶=86 r^2§=0.82 n=40	y=18+1.1x SEyE=52 r^2=0.91 n=40	y=36+1.1x SEyE=78 r^2=0.93 n=40
	Summer	y=71+0.8x SEyE=151 r^2=0.82 n=40	y=40+1.9x SEyE=179 r^2=0.92 n=40	
	Fall	y=87+0.5x SEyE=174 r^2=0.80 n=40	y=105+0.3x SEyE=251 r^2=0.75 n=38	
grasses	Spring	y=170+0.5x SEyE=153 r^2=0.72 n=40	y=98+0.8x SEyE=97 r^2=0.84 n=40	y=115+0.8x SEyE=87 r^2=0.94 n=40
	Summer	y=284+0.7x SEyE=283 r^2=0.72 n=40	y=237+0.9x SEyE=212 r^2=0.90 n=40	
	Fall	y=280+0.6x SEyE=335 r^2=0.73 n=40	y=273+1.1x SEyE=321 r^2=0.70 n=39	

†y=predicted component herbage mass.
‡x=visual estimate of component herbage mass.
¶SEyE=standard error of y estimate.
§r^2=coefficient of determination.

Table 3.3. Regression equations from double sampling that were used to predict herbage mass from visual estimates of cogongrass (CG), other forbs, and rhizoma perennial peanut (RPP) herbage mass (kg ha^{-1}).

Plant Fraction	1995	1996	1997
CG	y†=75+0.6x‡ SEyE¶=191 r^2§=0.72 n=158	y=44+1.5x SEyE=195 r^2=0.78 n=118	y=7.6+0.9x SEyE=64 r^2=0.85 n=40
other forbs	y=19+0.9x SEyE=105 r^2=0.88 n=160	y=15+0.9x SEyE=72 r^2=0.84 n=120	y=6.5+1.1x SEyE=36 r^2=0.89 n=40
RPP	y=399+0.7x SEyE=245 r^2=0.70 n=158	y=155+0.9x SEyE=228 r^2=0.90 n=120	y=252+0.6x SEyE=85 r^2=0.78 n=40

†y=predicted component herbage mass.
‡x=visual estimate of component herbage mass.
¶SEyE=standard error of y estimate.
§r^2=coefficient of determination.

and their interaction. All were tested using residual error as the error term.

Experiment 2

In the second study, younger RPP-mixed grass stands (less than 5 yr old) were fertilized in the spring as described for the first study. Spring N fertilization (0 vs. 35 kg N ha^{-1}) and spring grazing management (spring grazing and no spring grazing) were the treatments tested. Treatments were assigned in a split-plot arrangement of a randomized block design with three pasture replicates. Main plots were N rate, and level of spring grazing management was the subplot treatment. Each N rate by replicate combination was assigned to each pasture (pasture size range from 4 to 10 ha). Within each pasture, three sets of paired subplots (2.5 x 5 m; 15 m apart) were permanently marked with corner posts. One plot of each pair was enclosed to exclude cattle so that the area was ungrazed during April to June. The other plot of the pair was open allowing cattle access for grazing. Protected subplots were opened for grazing when herbage mass was above 3000 kg ha^{-1} (approximately the first week of July each year). Pastures were grazed to a 10- to 15-cm stubble height approximately every 21 d in the spring and every 14 d in the summer by individual cow/calf herds consisting of 30-50 cow/calf pairs. Herds moved sequentially across treatments within replicates from April to October.

Percentage of the components in total DM was determined for forbs [MT, blackberry, dogfennel (Eupatorium capillifolium L.)], grasses (bahiagrass and common bermudagrass), and RPP every 56 d throughout the 1995 and 1996 growing season and once in spring 1997. A double sampling technique was used. Prior to opening the protected plots in 1995, one double sample on a 0.25 m^2 quadrat (visual estimation of herbage mass and botanical composition), followed by clipping to a 2.5-cm stubble height was taken in each of the paired subplots (six double samples per N rate by replicate combination, total of 36). In 1996, five double samples were taken per pasture (total of 30). Prediction equations were generated as discussed previously (Table 3.4). A visual estimate was taken on each 1-m^2 permanently marked quadrat in each paired site every 56-d (April, June, August, and October of each year). Means of three visual estimations taken per treatment and the prediction equations generated from double sampling were used to predict mass of forbs, grasses, and RPP. Percentage of each component in total herbage mass was calculated as described previously.

Repeated measures analysis of variance procedures in PROC MIXED (SAS, 1989) were used to test the effects of

Table 3.4. Regression equations from double sampling that were used to predict herbage mass from visual estimates of forbs, grasses, and rhizoma perennial peanut (RPP) herbage mass (kg ha^{-1}) in Experiment 2.

Plant Fraction	1995	1996
forbs	y†=67+0.9x‡ SEyE¶=142 r^2§=0.96 n=36	y=32+1.1x SEyE=64 r^2=0.95 n=30
grasses	y=83+1.01x SEyE=239 r^2=0.81 n=36	y=63+0.96x SEyE=105 r^2=0.88 n=30
RPP	y=373+0.9x SEyE=374 r^2=0.79 n=36	y=166+0.9x SEyE=86 r^2=0.86 n=30

†y=predicted component herbage mass.
‡x=visual estimate of component herbage mass.
¶SEyE=standard error of y estimate.
§r^2=coefficient of determination.

treatments and sampling dates and their interactions on mass and percentage of each component. Statistical analyses were also performed to determine the effects of treatments on percentage unit changes in species composition from the beginning (spring 1995) to the end (spring 1997) of the trial. This analysis used PROC GLM of SAS (1989) to test the effects of N rate, grazing management, and their interaction.

Results

Experiment 1

There were no N rate by stocking rate by season interaction for percentage of botanical components in total herbage mass. There was, however, a season by N rate interaction effect on percentage of grasses (P=0.005) and RPP (P=0.06), but the percentage of MT (P=0.58), other forbs (P=0.71), and CG (P=0.55) was not affected (Fig. 3.1). Percentage of grasses other than CG did not differ between N_0 and N_{35} from spring 1995 through spring 1996, but grass percentage was greater for N_{35} than N_0 from summer 1996 through spring 1997. Grasses increased by seven percentage units (0.30 Mg ha^{-1}) from spring to summer 1996 for N_{35} treatment (Fig. 3.1). Rhizoma perennial peanut followed the opposite pattern declining by five percentage units from

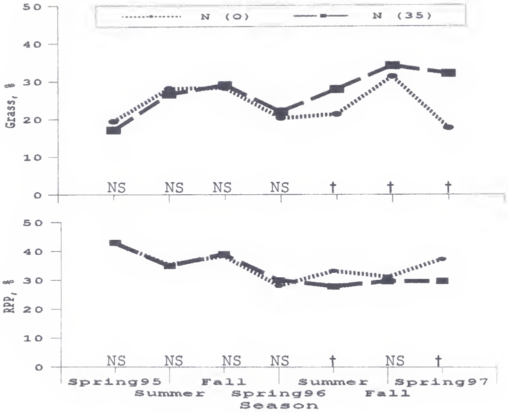


Fig. 3.1. Season by N rate interaction effects on proportion of grasses (P=0.005) and rhizoma perennial peanut (RPP) (P=0.06) in pastures. Data are percentage grass and RPP in total herbage mass across two stocking rates and two replicates. Symbols above the x-axis indicate results of treatment comparisons (NS, not significant; †, P<0.10).

spring to summer of 1996 for the N_{35} treatment. Percentage of RPP was relatively constant thereafter for the N_{35} treatment but increased for N_0. There were no N rate differences in percentage RPP in fall 1996 but there was N rate effect in spring 1997 (Fig. 3.1).

Changes in herbage mass of grass and RPP were similar to those described for percentage composition (Fig. 3.2). There was an N rate by season interaction for grass ($P=0.08$) and a trend for RPP ($P=0.13$). This was because grass herbage mass was greater for N_{35} than N_0 only from summer 1996 through spring 1997, but RPP herbage mass was lower for N_{35} than N_0 in summer 1996 only (Fig. 3.2).

There was a season effect on percentage MT ($P<0.001$), other forbs ($P<0.001$), and CG ($P<0.001$) in total herbage mass. Increases in percentage of MT in total herbage mass in the summer reflect growth of the plant during that season and no grazing of MT by cattle (Fig. 3.3). A notable seasonal change was the decrease of other forbs from spring to summer. These plants are mainly winter annuals which are dominant in the early spring but are senescent later in the year. Cogongrass increased from spring 1995 to spring 1996. A sharp increase observed in CG from fall 1995 to spring of 1996 was primarily the result of a late spring frost which reduced competition from other plants. Cogongrass was not

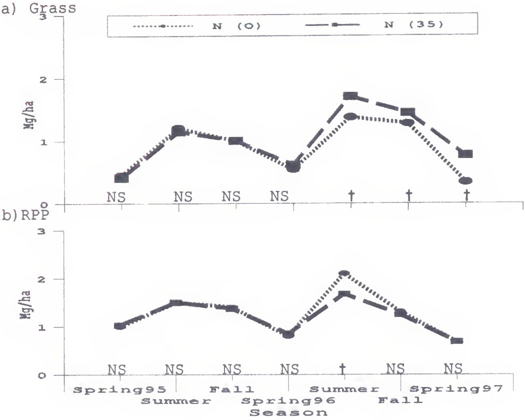


Fig. 3.2. Season by N rate interaction effects on herbage mass of a) grass (P=0.08), and b) rhizoma perennial peanut (RPP) (P=0.13) in pastures. Data are least square means of herbage mass across two stocking rates and two replicates. Symbols above the x-axis indicate results of treatment comparisons (NS, not significant; †, P<0.10).

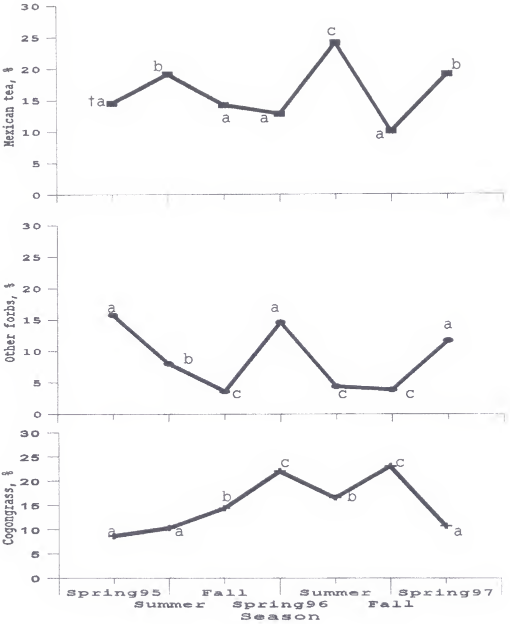


Fig. 3.3. Percentage of Mexican tea, other forbs, and cogongrass in total herbage mass of Rhizoma perennial peanut-grass pastures averaged across two N rates, two stocking rates, and two replicates from spring 1995 to spring 1997. †Least square means with a common letter are not different (P>0.10).

affected by the late frost as much as RPP and this caused a large increase in CG percentage.

When comparing the change in contribution of various vegetative components of total herbage yield (average across seasons) from 1995 to 1996, there was an N rate effect for grasses ($P=0.05$) and other forbs ($P=0.06$), but no effect on MT, CG, and RPP components of the sward (Fig. 3.4). There was no effect of stocking rate or interactions on this response. From 1995 to 1996 grass contribution to total herbage mass increased four percentage units for N_{35} but decreased two percentage units for N_0 (Fig. 3.4). The increase in grass percentage represented a 0.6 Mg ha^{-1} increase for N_{35}. There was a slightly greater decline in other forbs with N_0 than N_{35}, but the difference was probably not biologically important. Although unaffected by N treatment, there was an increase in the CG component of the sward for both N rates from 1995 to 1996.

Sward composition changed over the 2 yr of grazing. From spring 1995 to spring 1997, there was an eight percentage unit greater increase ($P=0.06$) in grass contribution with N_{35} than N_0 (Fig. 3.5). The increase in grass represented a 0.30 Mg ha^{-1} increase in DM. There was a trend for greater decline in percentage RPP ($P=0.11$; five percentage units) when N was applied relative to pastures receiving no fertilizer N. This change in percentage of

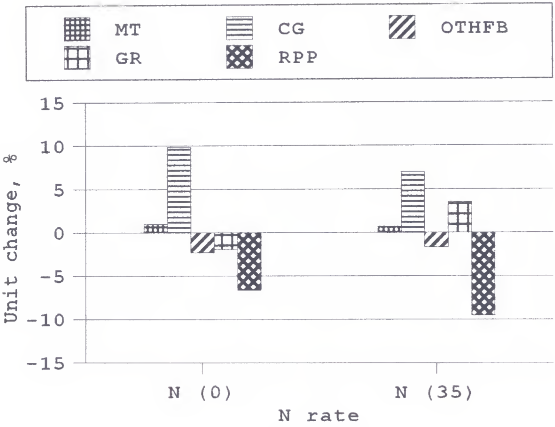


Fig. 3.4. Main effects of spring N rate on changes in average botanical composition of pastures from 1995 to 1996. Data are percentage unit increases or decreases in proportion of total herbage mass that is Mexican tea (MT; P=0.82), cogongrass (CG, P=0.30), other forbs (OTHFB, P=0.06), grasses (GR, P=0.05), and rhizoma perennial peanut (RPP, P=0.36).

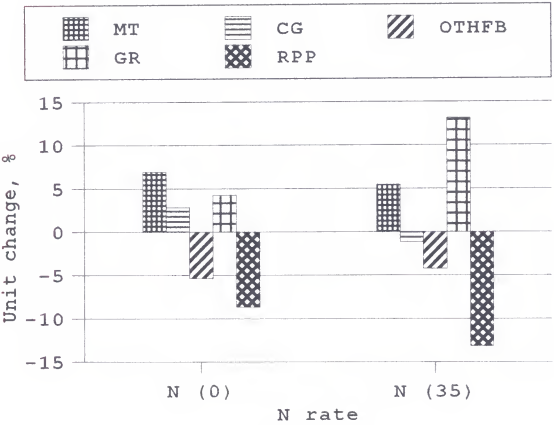


Fig. 3.5. Main effects of spring N rate on changes in average botanical composition of pastures from spring 1995 to spring 1997. Data are percentage unit increases or decreases in proportion of herbage mass of Mexican tea (MT; P=0.72), cogongrass (CG, P=0.47), other forbs (OTHFB, P=0.67), grasses (GR, P=0.06), and rhizoma perennial peanut (RPP, P=0.11).

RPP, however, was not due to differences in herbage mass of RPP (Fig. 3.2).

Experiment 2

There was no N rate by grazing management by sampling date interaction for percentage of any of the components in total herbage mass. There was an N rate by grazing management interaction effect on the percentage of grass ($P=0.05$) and RPP ($P=0.04$) in total herbage mass (Table 3.5), but not for forbs ($P=0.71$). Whether grazed in the spring or not, pastures receiving N_{35} had a higher percentage of grass and lower percentage of RPP than pastures that received no N. The percentage of grass increased by nine percentage units (0.5 Mg ha^{-1}) with N_{35} when grass was not grazed in the spring, but it increased only four units (0.2 Mg ha^{-1}) when grass was grazed. Pastures not grazed in the spring declined in RPP proportion by 11 percentage units due to added N fertilizer, but they declined only seven units due to N fertilization if spring grazing occurred. Interaction effects on percentage contribution of grass and RPP components should be interpreted with caution. As with Experiment 1, changes in proportion were due to an increase grass DM not a decline in RPP DM in the sward (Table 3.5).

Additionally, there was a sampling date by N rate interaction for forbs, grass, and RPP. Although there was a

Table 3.5. Interaction of spring N rate and spring grazing management on percentage of grass and rhizoma perennial peanut (RPP) in total herbage mass. Data are least square means across nine sample dates and three replicates.

	Spring Grazing Management			
N rate	No Grazing	Spring Grazing	No Grazing	Spring Grazing
kg ha^{-1}	Grass, %DM		RPP, %DM	
0	36a† (1.0)‡	38a (0.9)	53a (1.6)	52a (1.3)
35	45b (1.5)	42b (1.2)	42b (1.5)	45b (1.3)

†Least square means followed by the same letter within a column are not different (P>0.10).

‡Number in brackets represent yields in Mg ha^{-1}.

general increase in percentage of forbs over time regardless of N fertilizer, the percentage of forbs was higher with N_{35} for the June and August 1996 sampling dates (Fig. 3.6). The increase in forbs percentage in the summer of 1996 reflects increased forbs herbage mass (Fig. 3.7) and may have been due to the encroachment of MT which was essentially absent at the initiation of the study. Grass percentage was greater for the higher N rate at six of the nine sampling dates, and RPP proportion was lower for N_{35} than N_0 at seven of the nine sampling dates (Fig. 3.6).

The date by N rate interaction also affected the herbage mass of each component (Fig. 3.7). The comparison of N rates across time was similar for forbs and grass mass to that described for botanical composition, but RPP mass was reduced by N_{35} only in October 1996.

As with Experiment 1, there was an effect of N rate on change in percentage of the grass component in total herbage mass from the spring of 1995 to 1997 (Fig. 3.8). There was an eight percentage unit greater increase in grass contribution to the sward with N_{35} than N_0 (Fig. 3.8), representing a 0.30 Mg ha^{-1} greater increase in grass herbage mass relative to N_0 (Fig. 3.7). Conversely, there was nearly a 10 percentage unit greater decline in RPP with N_{35} than N_0 over the 2 year of the study. As with Experiment 1, this change in percentage contribution of RPP to the

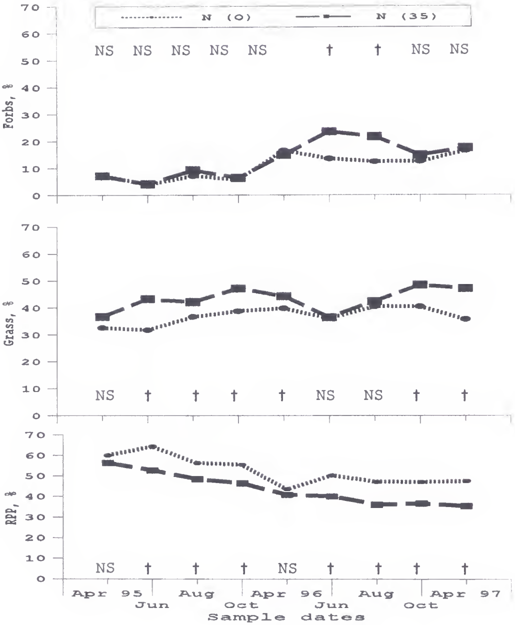


Fig. 3.6. Sampling date by N rate interaction on percentage of forbs (P=0.05), grass (P=0.01), and rhizoma perennial peanut (RPP) (P=0.003) in pastures. Data are least square means across two spring grazing treatments and three replicates. Symbols above the x-axis indicate results of treatment comparisons (NS, not significant; †, P<0.10).

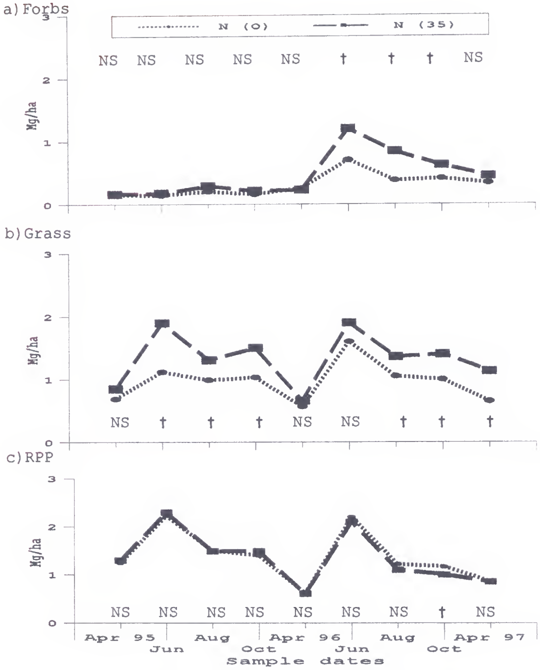


Fig. 3.7. Sampling date by N rate interactions on herbage mass of a) forbs (P=0.05), b) grass (P<0.001), and c) rhizoma perennial peanut (P=0.02) in pastures. Data are least square means across two spring grazing treatments and three replicates. Symbols above the x-axis indicate results of treatment comparisons (NS, not significant; †, P<0.10).

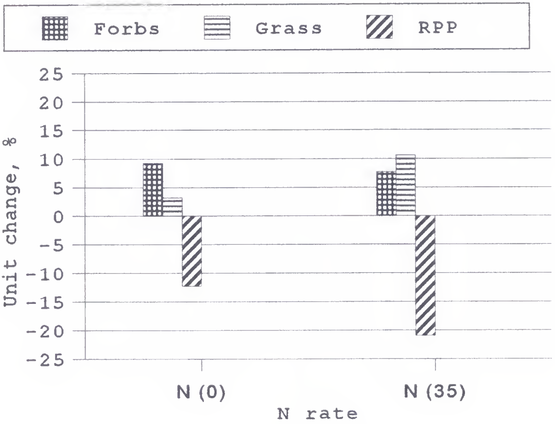


Fig. 3.8. Main effects of spring N rate on changes in average botanical composition of pastures from spring 1995 to spring 1997. Data are percentage unit increases or decreases in proportion of herbage mass of forbs (P=0.51), grass (P=0.008), and rhizoma perennial peanut (RPP, P=0.02).

sward was due to increases in grass herbage mass due to N_{35}. Although there was a general decline in RPP herbage mass from spring 1995 to spring 1997, there was no difference in herbage mass due to N fertilization (Fig. 3.7).

Discussion

Experiment 1

By the second year of the study, spring N fertilization of RPP-pastures increased the proportion of desirable grasses in total herbage mass by approximately four percentage units. Grass contribution in pastures receiving no N decreased slightly during the same time period. This effect of N fertilization on botanical composition after 3 yr of N application was more obvious by the spring of 1997 when desirable grass percentage of total herbage mass had increased by nine units more than swards receiving no N. Valentim et al. (1986) found that applying 150 kg ha^{-1} N to either a mixture of RPP-bermudagrass or RPP-bahiagrass increased bermudagrass contribution to the sward by 23 percentage units, but increased bahiagrass contribution by only three percentage units. They attributed the lack of response of bahiagrass to application of N to retention of large amounts of N in the stolons and root mass of the newly established bahiagrass sod. The mature stands of bahiagrass growing in association with RPP in this study probably explain the better response observed with much lower rates of N.

The effect of N fertilization on RPP contribution was less clear. Percentage of RPP declined an average of 8 units in both non-fertilized and N-fertilized swards from 1995 to 1996. By 1997, although for both swards there was still less RPP than in 1995, RPP contribution to the N fertilized sward was 5 percentage units lower than in the sward receiving no N (Fig. 3.4). This percentage decline in RPP is similar to what Valentim et al. (1986) found with applications of 150 kg ha^{-1} to RPP-bahiagrass associations where RPP contribution was reduced by nine percentage units. Both in the case of Valentim et al. (1986) and in the current experiment, declines in RPP percentage were due to increased grass contribution not to reductions in RPP mass. The net effect of N fertilization was increased total herbage mass. Valentim et al. (1986) observed that a mixture of RPP and bahiagrass resulted in a 100% increase in DM yield compared to bahiagrass alone regardless of N fertilization. They attributed this increase to more efficient utilization of light and nutrients. Increased herbage mass, regardless of the source, should have a positive effect on animal performance in this area of Florida in the spring. This is because the nutritive value of bahiagrass in the spring will support more than 1 kg d^{-1} daily gains, but availability of all forage types may be limiting (Williams et al., 1991). Higher amount of grass in the late summer may not be beneficial though if intake of RPP is affected by an increase in grass and overall diet quality declines. Studies with pure stands of RPP have indicated declining animal performance with grass encroachment (Prine et al., 1981). Further studies are necessary to determine the most acceptable level of RPP-mixed grass in mixtures.

Changes in proportion of MT and CG in herbage mass from spring 1995 to spring 1997 were not affected by N fertilization. This lack of effect did not support the original hypothesis of the study that N fertilization, by increasing grass competition, would decrease MT contribution. At no time during this study were increases in desirable grass component associated with decreases in MT. Because there is often a time lag for changes in botanical composition (Jones et al., 1995), several years of increasing grass percentage may be required to reach the point at which competition from the grass reduces the proportion of MT or other weedy forbs in the pasture. Another possibility for the lack of response of MT to increased competition from the grass could be the inability of the grass, regardless how vigorously growing, to compete with an established perennial that is not grazed. Bourdot (1996) noted that the main advantage of maintaining a competitive grass is the prevention of gaps at the soil surface that allow weed establishment. Mexican tea seedlings has been observed in disturbed sites in RPP swards (personal observation). This suggests that N applications may be more useful for weed control when used as a preventive measure.

There was no effect of stocking rate on changes in pasture composition over time. This could be because the stocking rates applied in the present experiment were both relatively low, and herbage mass remained above 2.0 Mg ha^{-1} on the high stocking rate for the entire grazing season in both years. Cameron et al. (1989) reported decreasing contribution of legumes with an increase in stocking rate. Jones (1979), observed that in a setaria (_Setaria sphacelata_)-siratro (_Macroptilium atropurpureum_) sward, grass contribution increased with increasing stocking rate.

Experiment 2

In the case of the no N fertilization treatment, the hypothesis that the competitive ability of bahiagrass suffer due to spring grazing was not supported by the results of this study. Grass DM increased by only 0.1 Mg ha^{-1} due to no spring grazing versus spring grazing for N_0 treatment compared to 0.3 Mg ha^{-1} for no spring grazing versus spring grazing for N_{35} (Table 3.5). This suggests that N is more limiting to grass competitiveness in the spring than the effects of grazing pressure. Similar to what had been observed in Experiment 1, there were no consistent changes in RPP DM due to N fertilization, and RPP DM was increased only by deferring grazing in the spring.

In spring 1997 after 3 yr of N fertilization, grass increased by eight percentage units in those pastures receiving N fertilization compared to spring 1995. Although there was a similar decline in percentage RPP (nine units) due to N fertilization compared to no fertilization, as in Experiment 1, this did not represent an actual decline in RPP DM availability. Enhanced grass contribution to the sward resulted in a net increase in total herbage availability. As observed in Experiment 1, there was no effect of N on forbs percentage in total herbage mass from spring 1995 to 1997. Forbs increased an average of eight percentage units from spring 1995 to 1997. So, although N fertilization was effective in increasing percentage of grass, there was no evidence from this study with younger RPP-mixed grass stands that N fertilization could limit the invasion of weedy forbs.

Summary and Conclusion

In the first experiment, percentage of grass and grass herbage mass were influenced by N treatment. Nitrogen fertilization reduced the percentage of RPP but had no effect on percentage of MT, other forbs, and CG. The relatively low stocking rates used in this study did not affect the botanical composition of RPP-mixed grass swards.

In the second experiment, the treatment combination of N fertilization with no spring grazing increased the percentage of bahiagrass more than any other treatment. This treatment also caused the greatest decline in RPP percentage in herbage mass. Forb encroachment (e.g., MT) was observed in both pastures, whether fertilized with N or not, indicating that the degree to which grass competition was increased in this study was not sufficient to inhibit invasion by this forb.

These data indicate that the grass component of RPP-mixed grass swards can be manipulated with even low N fertilizer rates. Nitrogen reduces RPP percentage in total herbage mass, but the reduction in RPP with zero N, suggests that MT and CG reduce RPP contribution probably by outcompeting RPP for light. General declines in RPP content of young swards between spring 1995 and spring 1997 suggest that weed encroachment may become a problem. It can be concluded that 35 kg ha^{-1} can be used to increase grass proportion and total herbage mass in RPP-mixed grass swards, but that other management or control methods are needed to minimize the encroachment of weedy grasses and forbs.

CHAPTER 4

MANAGEMENT EFFECTS ON PLANT, ANIMAL, AND DIET COMPOSITION RESPONSES ON CONTINUOUSLY STOCKED RHIZOMA PERENNIAL PEANUT-MIXED GRASS SWARDS

Introduction

Forage legumes can play a key role in determining the level of productivity from improved or native pastures by their direct effects on animal productivity. In subtropical Florida, rhizoma perennial peanut (RPP; *Arachis glabrata* Benth.), a tropical legume, has demonstrated attributes of excellent nutritive value (Prine et al., 1981; Williams et al., 1991), persistence (Ortega-S. et al., 1992a), and high productivity (Beltranena et al., 1981). Mixed RPP-grass swards have supported stocker cattle gains of 0.75 to 1.0 kg d^{-1} (Williams et al., 1991; Bennett et al., 1995) when grazed from April to October.

In existing RPP-grass pastures, the RPP component of the sward has been observed to increase at the expense of the grass (Prine et al., 1981), but as the sward ages, desirable grasses are thought to be replaced by weedy grasses and forbs (Williams et al., 1991). Pasture botanical surveys have shown a negative correlation between the presence of grass and forbs in RPP-grass swards (Harrelson et al., 1993). Williams (1994) observed differences in the relative growth rate of RPP and bahiagrass (Paspalum notatum Flügge), particularly during drought periods, and she suggested that this may be due to different mechanisms of drought tolerance of the species. Greater availability of grass compared to RPP during spring droughts is thought to be partially responsible for selective grazing of grass during this period (Harrelson, 1993) and may contribute to grass decline.

Pasture management can be used to manipulate the competitiveness of grasses and legumes in mixed swards. Nitrogen fertilization has been shown to favor the grass component (Hoveland and Richardson, 1992). Valentim et al. (1987) noted that biologically fixed N_2 of RPP was inadequate for the grass of the mixture to compete with the legume under multiple harvests for hay. Based on relative growth data of N-fertilized and unfertilized bahiagrass, Williams (1994) suggested that bahiagrass would need at least 56 kg N ha^{-1} to remain competitive with RPP. These studies indicate that N fertilization may be necessary to enhance the competitive ability of grasses grown in association with RPP. The amount of N required to increase the grass proportion in grazed RPP-grass swards is unknown.

Another management factor that can alter the competitive balance of grass-legume swards is stocking rate. Grazing studies in mixed RPP-grass pastures have shown that RPP is selectively grazed during the summer when RPP quality is superior to associated grasses (Harrelson et al., 1993). This suggests that varying intensity of grazing (e.g., stocking rates) may play a role in manipulating botanical composition of these swards. Varying intensity of grazing, including when animals can be selective and when they cannot, exerts considerable influence on the botanical composition of pastures (Kemp et al., 1996). Malechek (1984) noted that because most herbivores graze selectively, grazing intensity can play a major role in influencing the botanical composition of cattle diets. Guevara et al. (1994) suggested that evaluating changes in diet selection by cattle in grazing systems may be of assistance in quantifying livestock and pasture responses.

Research is needed with RPP-grass swards that measures the plant and animal responses to treatments designed to increase the competitiveness of the grass component. The objective of this study was to determine the effects of spring N fertilization and summer stocking rate on herbage mass (HM), nutritive value, herbage allowance (HA), and animal performance and diet botanical composition of grazed RPP-grass swards.

Materials and Methods

This experiment was conducted in 1995 and 1996 at the USDA, ARS, Subtropical Agriculture Research Station, Brooksville, FL (28° 37'N, 82° 22'W). Two adjacent 16-ha, 15-yr-old, RPP-grass swards were subdivided to make eight, 4-ha pastures and used for grazing studies. Pastures were predominantly mixed swards of RPP with bahiagrass and bermudagrass [*Cynodon dactylon* (L.) Pers], Mexican tea [MT; *Chenopodium ambrosoides* (L.)], cogongrass [CG; *Imperata cylindrica* (L.) Beauv], and blackberry (*Rubus cuneifolius* Pursh). The predominant soil was a Candler fine sand (hyperthermic, uncoated, Typic Quartzipsamment) with very low water holding capacity.

Mean soil pH and Mehlich I extractable P and K at the site were 5.7 and 104 and 64 mg kg^{-1}, respectively. Pastures were fertilized in spring (14 Mar. 1995 and 15 Apr. 1996) with 13 kg P, 50 kg K, and either 35 (N_{35}) or 0 (N_0) kg N ha^{-1}. Due to a late frost in 1996, fertilizer was applied a month later that year.

Design and Grazing Management

Pasture and animal responses were measured using 4-ha pastures as experimental units. Nitrogen rates (0 vs. 35 kg ha^{-1}) and summer stocking rates (1.5 and 2.5 bulls ha^{-1}) were tested. Treatments were arranged in a two by two factorial in a randomized block design consisting of two pasture replicates.

Sixty-four yearling bulls were assigned in a stratified manner (by weight class and breed) to each pasture prior to the initiation of the grazing study. In April 1995 and May 1996, yearling bulls [n=48, 370 ± 11 kg and 357 ± 8 kg shrunk weight (16 h feed and water fast) in 1995 and 1996, respectively] were placed on the experimental pastures. Additional bulls (n=16) were maintained in an adjacent RPP-grass pasture at a similar stocking rate. Purebred Angus (n=12, *Bos taurus*), Senepol (n=20, a tropically adapted *B. taurus*), and Brahman (n=32 , *B. indicus*) were used in 1995; in 1996 Angus (n=52) and Senepol (n=12) bulls were used.

Pastures were stocked at 1.5 animals ha^{-1} (6 head per pasture consisting of 3 Brahman, 2 Senepol, and 1 Angus in 1995 and 5 Angus and 1 Senepol in 1996) from spring (12 Apr. 1995 and 15 May 1996) until early summer (5 July 1995 and 11 July 1996). Starting at the end of the spring to early summer grazing period and continuing through the fall (28 Sept. 1995 and 3 Oct. 1996) the stocking rate was increased on half of the pastures to 2.5 bulls ha^{-1} (10 bulls per pasture) by the addition of extra bulls (2 Brahman, 1 Senepol, and 1 Angus in 1995 and 3 Angus and 1 Senepol in 1996).

Animal Responses and Measurement Techniques

At the initiation of the grazing experiment and at 28-d intervals, full weights, scrotal circumference (SC; cm), hip height (cm), and body condition scores (BCS; scale of 1 to 9; Kunkle et al., 1994) were taken for each bull. In addition, shrunk weights (16 h without feed and water) were taken at the beginning and at the end of the spring grazing season (i.e., when additional bulls were added to the high stocking rate treatment) and used to determine spring grazing season average daily gains (ADG; 84 and 56 d in 1995 and 1996, respectively). Shrunk weights were also taken at the end of the trial to determine summer grazing season gains (84 d each year). Full-season, shrunk ADG was calculated as the difference between initial and final shrunk weight of bulls that were on the study during both grazing seasons. Gain per hectare was calculated as the product of ADG and animal days per ha for spring and summer grazing seasons.

Blood samples for determination of plasma urea nitrogen (PUN) were collected (10 mL) from bulls by jugular venipuncture two times during the grazing season, in July when extra bulls were added and at the last weigh date of each year. Plasma was separated by centrifugation, frozen (-18°C), and subsequently analyzed for PUN by an automated colorimetric analysis based on the diacetyl monoxime method of Marsh et al. (1965; Technicon Industrial Method 339-01, Technicon Industrial Systems, Tarrytown, NY).

At two weigh days during the spring grazing season (10 May and 7 June 1995, and 13 June and 11 July 1996) and again at two weigh days during the summer grazing season (2 Aug. and 30 Aug. 1995, and 8 Aug. and 5 Sept. 1996), fecal grab samples (n=48 per sample time) were taken from individual bulls in a squeeze chute. Samples were dried at 60°C to constant weight, ground in a Wiley mill to pass a 1-mm screen, composited by weight, and used to determine diet botanical composition by microhistological analyses of plant fragments in the feces (Johnson et al., 1983; Williams, 1989). Microhistological analyses were based on differences in the micro-anatomical features of forage particles in fecal samples. The presence of RPP, grass, and forb was determined in systematically located microscopic fields (20 fields of view, 5 slides per sample for a total of 100 observations) at 125 X or 200 X magnification with a phase contrast microscope. Procedures developed by Williams (1989) and Harrelson (1993) were used for training in the identification of plant fragments. Relative composition of each sample was calculated by using a frequency to density conversion for each component (Fracker and Brischle, 1944) for each collection date. Means of the two sample dates in each period of each year were used to compare seasonal differences (spring vs. summer).

Plant Responses and Measurement Techniques

Pastures were sampled for HM prior to initiation of the grazing experiment in April 1995 and May 1996 (spring), in July 1995 and 1996 prior to the addition of extra bulls (summer), and at the end of the trial in October 1995 and 1996 (fall), using a double sampling technique (Ortega et al., 1992a). Herbage allowance (kg herbage DM per kg animal liveweight) was calculated for the spring, summer, and fall dates. Animal weights used in the spring were the sum of the average weights for the first weigh date. For the summer, it was the sum of average weights for the weigh date before the extra animals were added, and for the fall, it was the sum of average weights for the fall weigh date when HM was measured. Every 4 wk, 50 or more hand-plucked samples (representative of the diet observed to be consumed by bulls) were collected from each pasture. Hand-plucked herbage was severed from approximately the top 15 cm of the canopy at selected locations in each pasture at six dates in 1995 and five dates in 1996. All samples were dried at 60°C to constant weight, ground in a Wiley mill to pass a 1-mm screen, and used for crude protein (CP) determination (N x 6.25) on a DM basis following the procedures of Gallaher et al. (1975) and Hambleton (1977). In vitro organic matter disappearance (IVOMD) was determined using a modified two-stage digestion procedure (Moore and Mott, 1974).

Statistical Analysis

Due to different dates in the initiation of the study in 1995 and 1996 and varying composition of breed of bulls used in 1995 and 1996, data were analyzed by year. Repeated measures analysis of variance procedures were used to test the effects of treatments and sample dates on HM, HA, CP, IVOMD, ADG (full-weights only). Statistics were based on the univariate approach, assuming first-order autoregressive correlations among the repeated measures, and were conducted using the PROC MIXED procedure of SAS (Littel et al., 1996). To test breed differences in 1995 and 1996, PROC GLM (SAS, 1989) was used with breed included in the model and tested using replicate within N rate by stocking rate by breed for the error term. Sampling date for the variable PUN was included in model and tested using residual error. Animal variables tested included initial, final, and change (difference between initial and final) in body weight, SC, hip-height, BCS, and PUN of bulls. Breed differences were separated in 1995 using single degree of freedom contrasts for temperate (Angus [Bos taurus]) vs. tropically adapted (Senepol [Bos taurus] and Brahman [Bos indicus]) and Angus vs. Senepol. In both years, full-season shrunk ADG, seasonal differences in ADG (shrunk weights of spring and summer) and breeds were analyzed. Sources of variation were N rate, stocking rate, breed, and their interactions for both years. These were tested using replicate within N rate by stocking rate by breed for the error term. Season was included in the model as a subplot treatment in a split-plot arrangement, and season, season by N rate, season by stocking rate, season by breed, and season by N rate by stocking by breed were tested using residual error. There was a breed by season interaction in 1995, so data was sorted by season and re-analyzed by season. Breed differences were also separated in 1995 using single degree of freedom contrasts for temperate (Angus [Bos taurus]) vs. tropically adapted (Senepol [Bos taurus] and Brahman [Bos indicus]) and Angus vs. Senepol. Gain per hectare and seasonal diet composition were analyzed as a randomized block design (SAS, 1989). Sources of variation were N rate, stocking rate, and their interactions for both years. These were tested using residual error. Least squares means for gain ha^{-1}, and diet composition, when different were separated using PDIFF (SAS, 1989).

Results

Herbage Mass and Herbage Allowance

There were no treatment by season interactions for HM, nor was HM affected by N rate or stocking rate either year. Average HM did not differ in the 2 yr, and in 1995 and 1996 was 3.0 ± 0.12 Mg ha^{-1} and 3.4 ± 0.13 Mg ha^{-1}, respectively. Herbage mass was affected by season in 1995 ($P<0.001$) and 1996 ($P<0.001$; Table 4.1). These differences were probably an effect of rainfall (Table 4.2) and other climatic factors on growth of pasture plants.

Herbage allowance was affected by a stocking rate by season interaction in 1995 ($P<0.001$) and 1996 ($P=0.04$). Differences between stocking rates occurred only for the fall sampling date (Figs. 4.1 and 4.2), reflecting the changes in the stocking rate that occurred in summer.

Nutritive Value

Herbage CP and IVOMD of hand-plucked samples were not affected by N rate or stocking rate or their interaction either year. Additionally, there were no treatment by season interactions. Least squares means of CP and IVOMD concentrations averaged 170 ± 4.2 g kg^{-1} and 605 ± 9.4 g kg^{-1} in 1995 and 170 ± 4.7 g kg^{-1} and 606 ± 7.6 g kg^{-1} in 1996,

Table 4.1. Seasonal effects on herbage mass (HM) and its components, forb (FB), grass (GR), and rhizoma perennial peanut (RPP) in 1995 and 1996.

	1995				1996			
Season	FB	GR	RPP	HM	FB	GR	RPP	HM
	----------------------Mg ha^{-1}-------------------							
Spring	0.70a†	0.40a	1.00a	2.10a	0.80a	0.60a	0.80a	2.20a
Summer	1.20b	1.20b	1.50b	3.90b	1.70b	1.50b	1.90b	5.00b
Fall	0.60a	1.00b	1.40b	3.00c	0.60b	1.40b	1.30c	3.00c

†Least squares means within a column followed by common letters are not different using PDIFF (P>0.05).

Table 4.2. Monthly rainfall during the 1995 and 1996 grazing seasons and the 30-year mean at the Subtropical Agriculture Research Station, Brooksville, FL.

	Year		30-yr
Month	1995	1996	average
	mm		
April	98	90	57
May	78	97	111
June	246	136	169
July	177	52	195
August	360	143	220
September	248	78	166
October	274	67	61
Total	1481	663	979

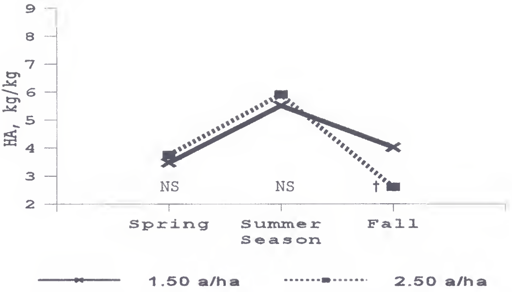


Fig. 4.1. Effect of stocking rate on herbage allowance (HA) of rhizoma perennial peanut-mixed grass swards in 1995. Symbols above the x-axis are results of stocking rate comparison (NS, not significant; †, P<0.10).

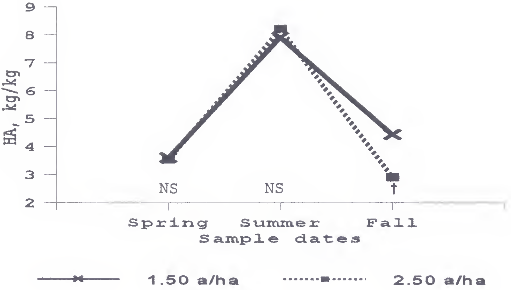


Fig. 4.2. Effect of stocking rate on herbage allowance (HA) of rhizoma perennial peanut-mixed grass swards in 1996. Symbols above the x-axis are results of stocking rate comparison (NS, not significant; †, P<0.10).

respectively. Sample date differences (P<0.001) were observed in both years for CP and IVOMD (Figs. 4.3 and 4.4). For both years, CP concentrations ranged from approximately 200 g kg^{-1} (April/May) to 140 g kg^{-1} (September). The pattern was similar for IVOMD which ranged from approximately 650 at the beginning to 540 g kg^{-1} at the end of grazing.

Diet Selection

There was no effect of N rate, stocking rate, or their interactions on diet botanical composition in 1995 and 1996. In 1995, there was a season effect on diet composition for grass (P=0.02) and forb (P<0.001), but not for RPP (P=0.78; Table 4.3). In 1996, season differences in diet composition were observed for RPP (P<0.001), grass (P<0.009), and forb (P=0.01); (Table 4.4). Because changes in diet composition were not associated with changes in botanical composition, these data indicate that cattle selected for RPP in both the spring and summer of 1995 and 1996. As can be observed from HM data (Table 4.1), RPP contributed nearly 40% of the sward DM in both seasons of 1995 and 1996. Both years, grass proportion in the diet was greater than in pasture HM in spring (Tables 4.3 and 4.4). In the summer of 1995, the grass proportion in the diet was higher than in the pasture HM, but this was not the case in 1996, as there was an

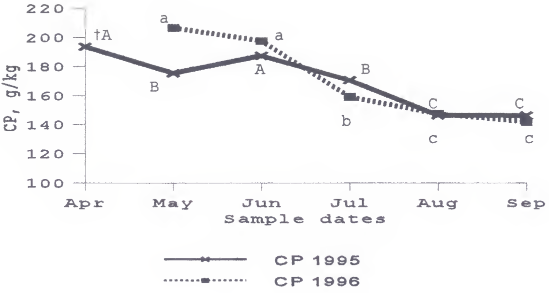


Fig. 4.3. Effect of date on crude protein (CP) concentration of hand-plucked herbage of rhizoma perennial peanut-mixed grass swards in 1995 and 1996. †Least squares means with common upper case letter (1995) or lower case (1996) are not different (P>0.10).

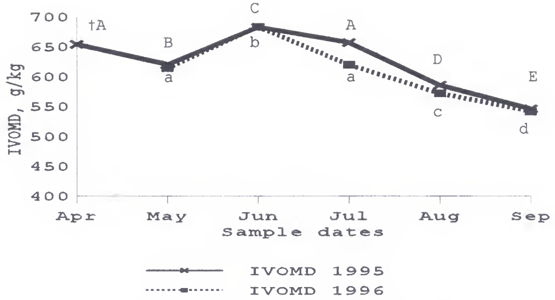


Fig. 4.4. Effect of date on in vitro organic matter disappearance (IVOMD) in hand-plucked herbage of rhizoma perennial peanut-grass swards in 1995 and 1996. †Least squares means with common upper case letter (1995) or lower case (1996) are not different (P>0.10).

Table 4.3. Effect of season on percentage of rhizoma perennial peanut (RPP), grass, and forb in the diet of bulls grazing rhizoma perennial peanut-grass swards in 1995.

Season	Components RPP	 Grass	 Forb
	----------------	%	--------------------
Spring	62 (48)†	33 (20)	5 (32)
Summer	61 (39)	39 (31)	0 (30)
‡P	0.78	0.02	0.001

†Numbers in brackets represent percentage of pasture HM of each component within season.

‡Probability value of season F test for percentage of RPP, grass, and forb in the diet.

Table 4.4. Effect of season on percentage of rhizoma perennial peanut (RPP), grass, and forb in the diet of bulls grazing rhizoma perennial peanut-grass swards in 1996.

	Components		
Season	RPP	Grass	Forb
	%		
Spring	62 (37)†	33 (27)	5 (36)
Summer	83 (38)	17 (30)	0 (36)
‡P	0.001	0.009	0.01

†Numbers in brackets represent proportion of pasture HM of each component within season.

‡Probability value of season F test for percentage RPP, grass, and forb in the diet.

apparent discrimination against grass. In the current study, although total rainfall was higher than normal (1481 mm; Table 4.2) in 1995, HM at the start of the study was lower than in 1996 (2.0 vs. 2.2 Mg ha^{-1} for 1995 and 1996, respectively). Herbage mass of all pasture components in the summer of 1996 (5.0 Mg ha^{-1}) was higher, than 1995 (4.0 Mg ha^{-1}) which may indicate a better rainfall distribution that summer. The resultant increase in under-grazed and mature grasses may have caused cattle to alter diet selection. Forbs contributed more than 30% of sward DM in both years. Forbs were, however, a minor component in the diet and were consumed only in the spring. Animals were observed to graze the most palatable winter annuals in the early spring.

Management Effects on Bull Performance

There were no effects of treatment, season, or their interactions on full-season ADG in 1995 and 1996. This may be due to the high nutritive value of the forage (Figs. 4.3, and 4.4) and the fact that HM was not limiting throughout the year (Table 4.1). Average daily gain for the entire year of grazing (spring and summer) were 0.61 ± 0.03 and 0.60 ± 0.02 kg d^{-1} for 1995 and 1996, respectively. There were breed differences ($P<0.001$) in 1995 and 1996. Average daily gain of the temperate (Angus [0.46 ± 0.05 kg d^{-1}])

breed was lower than tropical (Senepol [0.68 ± 0.03 kg d^{-1}] and Brahman [0.70 ± 0.03 kg d^{-1}]) breeds in 1995. Senepol ADG was higher ($P<0.001$) than Angus ADG. In 1996, Senepol ADG (0.80 ± 0.04 kg d^{-1}) was higher than ADG for Angus (0.58 ± 0.03 kg d^{-1}). Average daily gains of bulls differed ($P<0.001$) across 28-d weigh periods in 1995 and 1996 (Fig. 4.5). These changes in ADG may have resulted from the decline in nutritive value of the forage.

There were no N rate, stocking rate, or N rate by stocking rate interaction effects on seasonal (spring or summer) ADG. There were, however, seasonal differences ($P<0.001$) in ADG in 1995 and 1996 (Table 4.5). Spring ADG was more than 0.20 kg d^{-1} greater than summer ADG in both years. Herbage mass for the summer of 1995 and 1996 was consistently greater than 3 Mg ha^{-1} (Table 4.1). In addition, HA increased from 3 kg kg^{-1} in the spring to 6 to 8 kg kg^{-1} in the summer with no improvement in ADG (Fig. 4.5), suggesting that HA was not limiting ADG. Average daily gain was higher in the spring and declined throughout the year, consistent with seasonal changes in forage nutritive value (Figs. 4.3 and 4.4). These indicate that seasonal differences in forage nutritive value likely explain most of the differences in ADG. There was also a season by breed interaction in 1995. This appears to be due to a lesser decline in ADG from spring to summer for Brahman

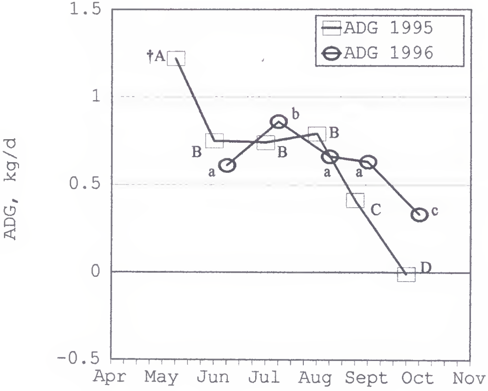


Fig. 4.5. Average daily gains (ADG) of bulls for 28-d periods on rhizoma perennial peanut-grass swards. Points on the graph are plotted on the last date of each 28-d period. †Least squares means within years with common letters are not different (P>0.10).

Table 4.5. Least squares means for yearling bull average daily gain by season in 1995 and 1996.

Season	1995	1996
	----------------kg d^{-1}---------------	
Spring	0.74 ± 0.04†	0.75 ± 0.03
Summer	0.51 ± 0.04	0.54 ± 0.03
P‡	0.01	0.008

† Least squares means ± standard error.

‡ Probability value of season F test.

than for Angus or Senepol (Table 4.6). In the spring, ADG was lower in temperate (Angus) contrasted with tropical breeds (Senepol and Brahman; P=0.004). Average daily gain for Angus was also lower than Senepol (P=0.001). These same differences were observed in the summer. In 1996, there was also breed differences (P=0.006) because ADG of Angus (0.60 ± 0.02) was lower than Senepol (0.80 ± 0.04).

Plasma urea N was not affected by N rate, stocking rate, breed, or their interaction in 1995. There was a breed by sampling date interaction in 1995, but not in 1996. Breed differences (P<0.001), however, were consistent in 1995 and 1996. The contrast between tropical breeds, Brahman (22 ± 0.44 mg dL^{-1}) and Senepol (24 ± 0.54 mg dL^{-1}) and Angus showed that PUN was three to five units higher in tropical than in Angus bulls (19 ± 0.54 mg dL^{-1}; P<0.001). In 1996, PUN values in Senepol (22 ± 0.60 mg dL^{-1} were also higher than Angus (19 ± 0.32 mg dL^{-1}; P=0.007). In addition, PUN in 1996 was affected by stocking rate (P=0.05) and sampling date (P=0.002). At 1.5 bulls ha^{-1}, PUN values (19 ± 0.56 mg dL^{-1}) were lower than those for 2.5 bulls ha^{-1} (21 ± 0.60 mg dL^{-1}). In summer (early July), PUN (21 ± 0.49 mg dL^{-1}) was higher than at the end of the year (early October; 18 ± 0.47 mg dL^{-1}).

Initial, final, and change in body weight, SC, hip height, and BCS were not affected by N rate, stocking rate,

Table 4.6. Least squares means for breeds by season average daily gain in 1995.

	Breeds			P values for contrasts	
Season	Angus	Senepol	Brahman	Temp. vs. Tropical†	Angus vs. Senepol
	----------------kg d^{-1}------------------				
Spring	0.53 ± 0.07‡	0.72 ± 0.04	0.88 ± 0.05	0.004	0.001
Summer	0.28 ± 0.05	0.60 ± 0.03	0.44 ± 0.04	<0.001	0.028

† Temperate=Angus; Tropical=Senepol and Brahman.

‡ Least squares means ± standard error.

breed or their interaction in 1995 and 1996. There were significant breed differences for most of the response variables in 1995 and 1996, except for BCS (Tables 4.7 and 4.8). In 1995, initial and final body weight (P<0.001) and change (P=0.002) was lower in temperate (Angus) contrasted with tropical (Senepol and Brahman; P<0.001). Both years, initial and final body weight were lower for Angus than Senepol (P<0.001) and in 1995 change in body weight was less for Angus compared to Senepol (P=0.004). In 1996, however, Angus and Senepol did not differ in change in body weight (P=0.11). Initial SC did not differ for temperate vs. tropical breeds due to the small initial SC of Brahman. Brahman are known to be slower to reach sexual maturity than most B. taurus breeds (Chase et al., 1993), and this is reflected in their initial SC. By the end of the study period in 1995, final SC of tropically adapted breeds was greater than temperate Angus (P=0.01), but change in SC was not different (P=0.07). Senepol had larger initial SC than Angus in 1995 but not in 1996. Even though Senepol had larger final SC than Angus in both years, change in SC did not differ consistently between these breeds. Initial hip height differences were observed for temperate vs. tropical breeds (P=0.001) and for Angus vs. Senepol (P=0.001). Final hip height measurements showed a similar pattern (P<0.001), but no difference in change in hip height were observed for

Table 4.7. Least squares means for effect of breed on initial, final, and changes on body weight (BW), scrotal circumference (SC), hip height (HH), and body condition score (BCS) in 1995.

Variable	Angus	Senepol	Brahman	P values for contrasts	
				Temp. vs. Tropical†	Angus vs. Senepol
BW					
Initial, kg	302 ± 13.4‡	433 ± 9.4	379 ± 7.7	0.001	0.001
Final, kg	377 ± 7.7	550 ± 10.4	495 ± 8.5	0.001	0.001
Change, kg	75 ± 10.9	117 ± 7.7	117 ± 6.3	0.002	0.004
SC					
Initial, cm	28.6 ± 1.10	31.9 ± 0.78	27.9 ± 0.64	0.28	0.02
Final, cm	30.0 ± 0.92	34.0 ± 0.65	31.4 ± 0.53	0.01	0.001
Change, cm	1.4 ± 0.69	2.1 ± 0.48	3.5 ± 0.48	0.07	0.40
HH					
Initial, cm	110 ± 1.87	131 ± 1.32	135 ± 1.08	0.001	0.001
Final, cm	115 ± 2.07	138 ± 1.47	144 ± 1.20	0.001	0.001
Change, cm	5 ± 2.12	7 ± 1.51	9 ± 1.22	0.27	0.54
BCS (scale 1 to 9)					
Initial	7.0 ± 0.27	7.2 ± 0.19	6.8 ± 0.16	0.92	0.57
Final	5.9 ± 0.19	6.1 ± 0.13	6.0 ± 0.11	0.32	0.28
Change	-1.1 ± 0.29	-1.1 ± 0.20	-0.8 ± 0.17	0.48	0.86

†Temperate=Angus; Tropical=Senepol and Brahman.
‡Least squares means ± standard error.

Table 4.8. Least squares means for effect of breed on initial, final, and changes on body weight (BW), scrotal circumference (SC), hip height (HH), and body condition score (BCS) in 1996.

Variable	Angus		Senepol		P value
BW					
Initial, kg	377	± 4.2†	460	± 9.4	0.001
Final, kg	458	± 3.8	564	± 8.7	0.001
Change, kg	81	± 3.1	104	± 6.9	0.11
SC					
Initial, cm	31.3	± 0.40	32.1	± 0.89	0.53
Final, cm	32.1	± 0.40	35.1	± 0.88	0.001
Change, cm	0.8	± 0.23	3.0	± 0.52	0.02
HH					
Initial, cm	116	± 0.77	129	± 1.73	0.001
Final, cm	120	± 0.62	133	± 1.39	0.001
Change, cm	4	± 0.66	4	± 1.48	0.89
BCS (scale 1 to 9)					
Initial	6.7	± 0.07	6.5	± 0.16	0.26
Final	6.8	± 0.10	6.8	± 0.23	0.89
Change	0.1	± 0.09	0.3	± 0.21	0.61

†Least squares means ± standard error.

tropical vs. temperate (P=0.27) or Angus vs. Senepol (P=0.54) in 1995. Initial, final, and change in BCS were not different for tropical vs. temperate in 1995 or Senepol vs. Angus in both years. In 1995, all the breeds lost one unit BCS despite gaining weight (Table 4.7). This was not the case in 1996, where bulls maintained BCS. It is probable that bulls in 1995 used energy reserves to maintain weight gains. Differences observed in initial and final body weight, SC, and hip height reflect the reproductive development and growth of the bulls.

Gain per hectare tended to be higher (P=0.15) in 1995 when pastures received N_{35}, but not in 1996 (Table 4.9). Increasing stocking rate tended (P=0.11) to increase gain per hectare in 1995 and did increase it in 1996 (P=0.08; Table 4.10). Because ADG was not affected by stocking rate, increase in gain per hectare was due solely to increasing stocking rate.

Discussion

Herbage Mass and Herbage Allowance

Seasonal differences observed in HM were probably a function of rainfall (Table 4.2), temperature, and daylength. Spring herbage mass likely was limited by lower rainfall and temperature than summer or fall, and decreasing

Table 4.9. Effect of N rate on gain ha^{-1} of bulls grazing rhizoma perennial peanut-grass swards in 1995 and 1996.

	Year	
N rate	1995	1996
kg ha^{-1}	----------------kg ha^{-1}--------------	
0	160 ± 6.2†	144 ± 12.4
35	179 ± 6.2	154 ± 12.4
‡P	0.15	0.59

†Least squares means ± standard error.
‡Probability value of treatment F test.

Table 4.10. Effect of stocking rate on gain ha^{-1} of bulls grazing rhizoma perennial peanut-grass swards in 1995 and 1996.

Stocking rate	Year 1995	Year 1996
	kg ha^{-1}	kg ha^{-1}
1.5	160 ± 6.2†	127 ± 12.4
2.5	179 ± 6.2	171 ± 12.4
‡ P	0.11	0.08

† Least squares means ± standard error.

‡ Probability value of treatment F test.

daylength and lower rainfall, particularly in September and October 1996, likely reduced fall HM relative to summer. An increase in HM from spring to summer was expected because a relatively low stocking rate (1.5 animals ha^{-1}) was used during the spring. Although low, the stocking rate was similar to that recommended for use on RPP-grass swards on this soil type in Florida (Williams et al., 1991). This stocking rate is recommended because HM in mid-April often is 2.0 Mg ha^{-1} or less due to spring droughts. Increase in HM is usually observed at the initiation of the rainy season in June or July. Seasonal variation in HM in this study was similar to that reported by Harrelson (1993).

In the current study, HA was 3 kg kg^{-1} or higher in spring and early summer indicating an excess of forage prior to increasing stocking rate. In previous work, McCartor and Rouquette (1977) observed that for continuously stocked pastures of pearl millet (Pennisetum glaucum L.) there was a linear increase in ADG with increasing HA only up to 1 kg kg^{-1}. Above that level of HA, ADG was not affected by HA. Similar responses have been observed for other forages (L.E. Sollenberger, 1997, personal communication). The increase in stocking rate did result in differences in HA for the fall period, but HA never fell below 2 for either stocking rate treatment. Further, the lack of a stocking rate by date interaction for ADG supports the argument that this reduction in HA was not limiting animal performance. Thus, ADG in this study was not limited by HA, but was limited only by the nutritional value of the forage and genetic potential of the bulls.

Nutritive Value

Crude protein concentration (170 g kg^{-1}) and IVOMD (605 g kg^{-1}) were high in both years in this study. For both years, CP concentrations ranged from approximately 200 g kg^{-1} (April/May) to 140 g kg^{-1} (September). Williams et al. (1991) reported a slightly higher range of values (245 to 190 g kg^{-1}) for similar periods, but RPP HM was more than 40% of the sward during that study. Concentration of IVOMD ranged from approximately 650 at the beginning to 540 g kg^{-1} at the end of grazing. Similar seasonal decline in IVOMD was reported by Harrelson (1993), although the range was slightly higher (780 to 610 g kg^{-1}) than those in the current study. Decreasing nutritive value throughout the year can be attributed to increasing maturity of the undergrazed herbage, to changes in leaf to stem ratio, and/or to an increase in grass proportion in the canopy. Grass species CP (e.g., bahiagrass) has been shown to decline in the summer to 70 g kg^{-1} or lower (Moore et al., 1969; Williams et al., 1991). Even RPP, will decline in nutritive value as the plant ages.

Diet Selection

In the current study, cattle diets in the spring and summer of both years contained a greater percentage of RPP than was in total herbage mass. Lascano and Thomas (1988) noted that in *A. pintoi*-grass swards cattle selected legume in a higher proportion than was present in the forage on offer in both the wet and dry seasons. Work by Harrelson (1993) indicated that RPP was selectively grazed in both spring and summer, and the degree of selection was dependent on forage availability. Rhizoma peanut HM was not limiting in either year (Table 4.1) and made up more than over 40% of the sward. Cattle consumed grass in similar proportion to that present in the forage on offer in 1995 in the summer, but in 1996 there was an apparent discrimination against grass (Table 4.3). Coates (1996) observed that in a grass-*Stylosanthes* spp. pasture, preference for grass was strongest in the early wet season. In the current study, although total rainfall was higher (Table 4.2) in 1995, HM at the start of the study was lower than in 1996 (Table 4.1). The sandy soils at this study site have very low water holding capacity, and rainfall distribution during the late spring and summer period is often more critical than absolute amount. August rainfall in 1995 was twice as much rainfall than in 1996 (360 vs. 143 mm, respectively), but records show that 130 mm occurred the first 2 d of the month and 110 the last week of the month. Higher HM in the summer of 1996 compared to 1995 suggest that rainfall distribution, particularly in August 1996, was better than 1995. Studies have shown that factors that limit growth rate of tropical grasses slow the rate of nutritive value decline (Minson and Wilson, 1980). This probably explains the difference in bull preference of grass component in 1995 compared to 1996.

Bull Performance

Average daily gains during the entire season of grazing (summer and spring) for both years were 0.60 kg d^{-1}. Full-season ADG was lower than the overall ADG of 0.70 kg d^{-1} reported by Bennett et al. (1995) and 0.80 kg d^{-1} reported by Williams et al. (1991). The lower gains observed in this study are probably due more to the lower growth potential of purebreds versus crossbreds used in the other study than to any great differences in nutritive value or HA of the RPP-grass swards. For both of the previous studies, implanted crossbred steers were used which were wintered at a relatively moderate rate of gain (approximately 0.5 kg d^{-1}). The purebred bulls used in this study were wintered to gain close to 1 kg d^{-1}. Thus it is possible that the crossbred steers in the previous studies may have exhibited some compensatory gains going on RPP-mixed grass pastures as opposed to the purebred bulls. Average daily gains of the tropical breeds, Senepol (0.68 kg d^{-1}) and Brahman (0.70 kg d^{-1}), were higher than Angus (0.46 kg d^{-1}) in 1995, and similar differences in ADG between Senepol and Angus were observed in 1996. Lower gains for Angus were probably a result of their being closer to their mature size during the grazing period. Chase et al. (1993) reported that Angus bulls are smaller framed than Senepol or Brahman. Additionally, ADG of Angus during the summer in subtropical Florida is probably reduced due to their lower heat tolerance compared to Senepol or Brahman (Hammond et al., 1996).

A comparison of spring and summer grazing seasons showed 25% greater ADG for the spring relative to summer (Table 4.5). These data suggest that grazing RPP-mixed grass swards early in the spring can be advantageous, provided there is enough rainfall for plant growth and HM is not limiting.

Plasma urea N values were above 19 mg dL^{-1} in both years of the current study and were similar to those found in previous studies with RPP-grass (Williams et al., 1991; Harrelson, 1993). Lower concentrations of PUN were observed in Angus bulls (19 ± 0.56 mg dL^{-1}) compared to Senepol (22 ± 0.60 mg dL^{-1}) or Brahman (22 ± 0.44 mg dL^{-1}). Chase et al.

(1993) reported lower concentrations of PUN in Angus compared to Senepol bulls and suggested that this reflected possible differences in protein utilization between breeds. In 1996, PUN was affected by stocking rate and sampling date. At 1.5 bulls ha^{-1}, PUN values (19 ± 0.56 mg dL^{-1}) were lower than those for 2.5 bulls ha^{-1} (21 ± 0.60 mg dL^{-1}), and in early summer, PUN (21 ± 0.49 mg dL^{-1}) was higher than at the end of the year (18 ± 0.47 mg dL^{-1}). These differences in PUN due to stocking rate and sampling date, however, were not biologically significant. Hammond (1997) noted that in healthy animals PUN concentrations are indicative of the energy to protein ratio in the diet (i.e., DOM:CP ratio). Hammond et al. (1993) noted that with tropical grasses there has been little benefit to supplemental protein when PUN was above 9 mg dL^{-1}. Concentrations of PUN between 9 and 12 mg dL^{-1} were a transition range below which ADG response to protein supplementation was greater and above which ADG response was lesser than the response within this range (Hammond, 1997). Results from the current study indicate that protein was not limiting gain at any time during the experiment and suggest that ADG could have been improved in the late summer or fall with energy supplementation.

Breed differences in body weight and hip height at the initial and final measurements as well as changes in body weight observed in the current study are associated with frame size and growth potential of the different breeds. Angus bulls have smaller frame size than Senepol or Brahman. Chase et al. (1993) noted that Senepol and Brahman were taller than Angus and at similar age and BCS would have heavier body weights. In the current study, SC for Angus at final measurement were smaller than either Senepol or Brahman. Difference in SC between Angus and Senepol were consistent in both years (Table 4.7 and 4.8). Similar SC for Angus was reported by Chase et al. (1997).

Gain per hectare did not increase greatly with N fertilization, a trend was observed only in 1995. Higher summer stocking rate tended to increase gain ha^{-1} in 1995 and did increase gain in 1996. Both the N rate and stocking rate used in this study were conservative, and higher levels of either one may have had greater impact on gain ha^{-1}.

Summary and Conclusions

Most plant and animal responses were not affected by N fertilization or stocking rate. Exceptions were liveweight gain per hectare which tended to or did increase with higher stocking rate and bull PUN which also was higher at the higher stocking rate in 1996, but the differences were not biologically significant. Seasonal effects were observed for most of the response variables measured. Herbage mass and HA were not limiting in either year and probably had little effect on ADG. Herbage nutritive value was higher in the spring and decreased throughout the year, suggesting that nutritive value was a major factor affecting ADG. Diet composition indicated that bulls consumed a greater proportion of RPP than in the pasture herbage mass in both spring and summer. Grass in the diet was 13 percentage units greater than in pasture HM in spring 1995 but only six percentage units greater in 1996. During summer 1995, grass in the diet was only eight percentage units greater than in the pasture, while in 1996 it was 13 percentage units lower. It appears that grass preference is reduced as grass increases in maturity and declines in nutritive value. As a result, some discrimination against grass will occur in the late summer in at least some years. The moderately high average daily gains observed in both the spring and the summer indicate that replacement bulls can achieve acceptable weight gains on RPP-mixed grass pastures from mid-April to September. Fertilization of RPP-mixed grass pastures increased grass contribution to the mixture (chapter 3) but had no effect on forage allowance, nutritive value, or bull ADG.

CHAPTER 5
SUSCEPTIBILITY OF PASTURE WEEDS AND TOLERANCE OF RHIZOMA PERENNIAL PEANUT-MIXED GRASS SWARDS TO HERBICIDE

Introduction

Rhizoma perennial peanut (RPP; *Arachis glabrata* Benth.) is a warm-season perennial forage legume with exceptional forage quality, high biomass production, long-term persistence, and multiple uses (Williams et al., 1991; Ortega-S. et al., 1992b; French et al.; 1994). In subtropical Florida, RPP provides herbage for grazing from April to October or two to three hay harvests per year. There are more than 4000 ha in full production in Florida (Williams et al., 1997).

Problems of weedy grasses and forbs invasion of RPP-mixed grass swards have recently been documented (Williams, 1994). Rhizoma perennial peanut-grass swards have not shown any apparent decline in RPP contribution (Williams et al., 1991), but pasture botanical surveys have shown a negative correlation between the presence of grass and weedy forbss in mixed RPP-mixed grass swards (Harrelson, 1993).

In Florida, high summer rainfall and daily maximum temperatures greater than 30°C provide a favorable environment for Mexican tea weed [MT; *Chenopodium ambrosoides* L.], with plants growing up to 1- to 1.5-m high and dominating RPP-mixed grass swards. Cogongrass [CG; *Imperata cylindrica* (L.) Beauv.], widely regarded as an invasive weed, is also favored by these growing conditions. It has invaded large areas of pasture and forestland in the state and is widespread along roadsides. Encroachment of these weeds on RPP-mixed grass swards represent a problem for hay and pasture producers. They compete directly with desirable forage species, lower the dollar value of the hay produced, and reduce its nutritional value. The vigorous growth and unpalatable nature of these weeds makes them difficult to control with grazing management alone.

Strategic use of herbicides to minimize weed impact and increase edible forage has not been assessed in RPP-mixed grass swards. Simpson and Langford (1996) suggested the use of herbicides as an option for manipulating pasture composition. Information on herbicide and herbicide rate effectiveness in controlling weeds and tolerance of desirable grass and legume species to herbicides can give added flexibility when considering management options for improving pastures. The rates at which herbicides are applied depend on the sensitivity of both the target weed and the desirable pasture species to the particular herbicide (Sandral et al., 1997).

Glyphosate [N-(phosphonomethyl)glycine] and triclopyr (3,5,6-trichloro-2-pyridinyloxyacetic acid) are two herbicides presently registered for use in pastures. Glyphosate is a nonselective herbicide, foliar-absorbed and inactive in the soil. Triclopyr is a systemic broad-leaf herbicide that is foliar-absorbed and degrades in the soil with microbial activity in 20 to 40 d (Ware, 1989). Fully established stoloniferous perennial peanut, A. pintoi Krap. et Greg., was found to be tolerant of glyphosate (Dwyer et al., 1989). Glyphosate has been reported to substantially reduce cogongrass infestations, but required multiple applications during the growing season (Gaffney, 1996). Triclopyr was effective in the control of sand blackberry, Rubus cuneifolius Pursh, in bahiagrass pastures, reducing its cover by 58 percentage units at a rate of 0.56 kg ha^{-1} (Kalmbacher and Eger, 1994).

The reduction or recovery rate of weeds and RPP DM after spraying are unknown. The objective of this study was to measure the effect of single summer applications of glyphosate (1.12, 2.24, and 3.36 kg ai ha^{-1}) and triclopyr (0.56, 1.12, and 1.68 kg ai ha^{-1}) on DM yield and botanical composition of weed-infested RPP-mixed grass swards.

Materials and Methods

This experiment was conducted in 1995 and 1996 at separate adjacent sites at the Land Use Unit of the USDA, ARS Subtropical Agriculture Research Station, Brooksville, FL (28°37' N, 82°22' W), on a Nobleton fine sand (clayey, mixed, hyperthermic, aquic, arenic, Paleudults). Experimental sites were located in RPP-mixed grass swards which were more than 10 yr old. Mexican tea was the dominant weed in the pasture in both years. Other weed species included blackberry and the annual sedge Cyperus esculentus. The major grasses were CG, bahiagrass, (Paspalum notatum Flügge), and common bermudagrass [Cynodon dactylon (L.) Pers]. Monthly rainfall for 1995, 1996, and the 30-yr average are reported in Fig. 5.1.

Herbicides were broadcast-applied on plots (3 x 7.6 m) on 30 June 1995 (0830 to 1030 h) and on 21 June 1996 (0830 to 1030 h). Treatments included an unsprayed control, a low, medium, and high rate of glyphosate (1.12, 2.24, and 3.36 kg ai ha^{-1}, respectively), and a low, medium, and high rate of triclopyr (0.56, 1.12, and 1.68 kg ai ha^{-1}, respectively). All treatments were applied using a CO_2-pressurized backpack sprayer with a hand-held boom (2.5-m wide, nozzle spacing 50-cm apart) equipped with 11003 flat fan nozzle tips delivering 215 L ha^{-1} at 276 kPa pressure.

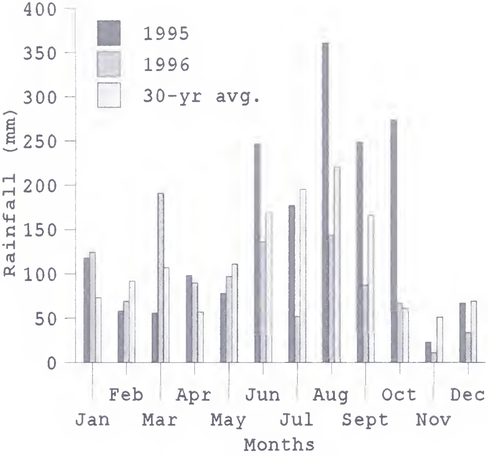


Fig. 5.1. Monthly rainfall in 1995 and 1996 and the 30-yr average at Brooksville, FL.

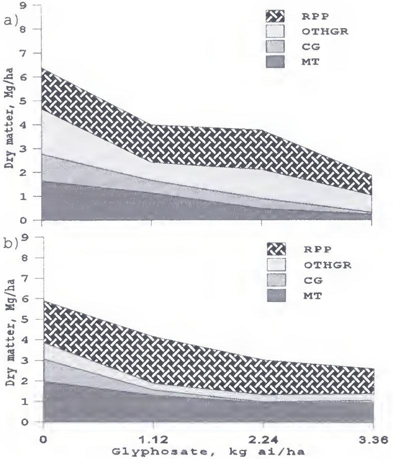
Herbage mass was determined 2 and 4 mo post application each year. In addition, the plots harvested 2 mo post spraying were harvested again 2 mo later. This is called the regrowth harvest in the results and discussion sections. At the time of first harvest, plots were divided into two subplots (3 x 3.8 m), one to be harvested at both 2 and 4 mo after application and the other only at 4 mo. Plots were harvested to a 2.5-cm stubble height using a sickle-bar mower. A 0.9- x 2-m strip was cut from the center of all harvested subplots. Two subsamples (approximately 400 g each) were taken, one for determination of DM concentration (dried to constant weight at 60°C) and the other for botanical hand separation. Botanical composition subsamples were separated into MT, CG, grass (other than CG), and RPP fractions, and dried at 60°C.

Treatments were arranged in a randomized complete block design and replicated six times. Data were analyzed as a split-split model using the GLM procedure of SAS (1989). In the first analysis, year was included in the model as a main plot treatment in a split-split-plot arrangement. There were significant year x treatment x harvest date interactions, so data were sorted by year and re-analyzed as a split-plot model. In this analysis, herbicide treatment was the main plot and time of harvest the subplot. Herbicide treatment by replication interaction was the error term for testing herbicide treatment. Residual error was the error term for testing time of harvest effects and treatment by time of harvest interactions. Treatment comparisons were made using single degree of freedom contrasts for linear, quadratic, and cubic effects of each herbicide. The control treatment was used as the zero rate for both herbicides.

Results

Glyphosate Effects on Dry Matter in 1995 and 1996

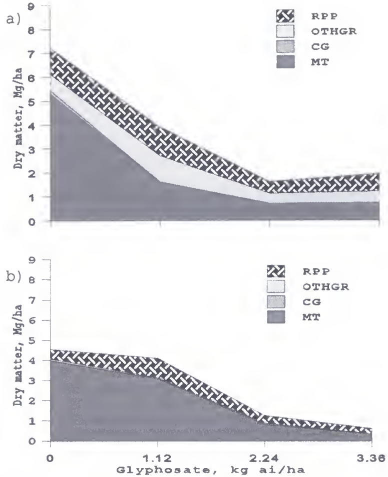
Both years there was a treatment by time of harvest interaction ($P<0.01$) for most response variables, so data were analyzed by time of harvest. When measured at 2 mo post application in 1995, MT DM decreased linearly ($P<0.01$) with increasing rates of glyphosate (Fig. 5.2 a,b). At the high rate there was an 86% reduction in MT DM relative to the control. At 2 mo post application (Fig. 5.3 a,b) in 1996, however, there was a quadratic effect ($P<0.01$) with most of the decrease in MT DM occurring between zero and the low rate of glyphosate (5.3 to 1.60 Mg ha^{-1} for zero and low rates, respectively). This represented a 70% reduction in MT DM, and the medium and high rates resulted in 88 and 94% reductions in DM, respectively, from that of the control. At 4 mo post application, a linear effect ($P<0.01$) of



Con-trasts†	2 month MT	CG	OTHGR	RPP	4 month MT	CG	OTHGR	RPP
GP-L	<0.01	0.31	0.13	0.02	<0.01	0.34	0.52	0.03
GP-Q	0.56	0.85	0.47	0.12	0.21	0.61	0.64	0.22
GP-C	0.54	0.81	0.22	0.25	0.96	0.89	0.82	0.50

†P values for glyphosate (GP) linear (GP-L) effect, GP quadratic (GP-Q) effect, and GP cubic (GP-C) effect.

Fig. 5.2 a,b. Effect of glyphosate (GP) rates on dry matter yield of Mexican tea (MT), cogongrass (CG), other grasses (OTHGR), and rhizoma perennial peanut (RPP) at (a) 2 and (b)4 mo post application in 1995.



	2 month				4 month			
Contrasts†	MT	CG	OTHGR	RPP	MT	CG	OTHGR	RPP
GP-L	<0.01	0.73	0.57	<0.01	<0.01	0.85	0.98	0.10
GP-Q	<0.01	0.77	0.71	0.46	0.57	0.98	0.97	0.06
GP-C	0.24	0.89	0.41	<0.01	0.98	0.90	0.96	0.04

†P values for glyphosate (GP) linear (GP-L) effect, GP quadratic (GP-Q) effect, GP cubic (GP-C) effect.

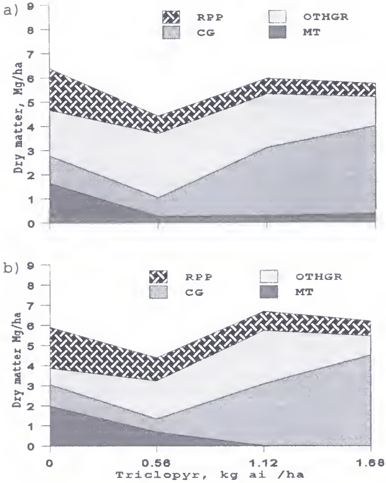
Fig. 5.3 a,b. Effect of glyphosate (GP) rates on dry matter yield of Mexican tea (MT), cogongrass (CG), other grasses (OTHGR), and rhizoma perennial peanut (RPP) at (a) 2 and (b) 4 mo post application in 1996.

herbicide rates was still observed on MT DM in 1995 (2.0 and 1.0 Mg ha^{-1} for zero and high rates) and in 1996 (4.0 and 0.40 Mg ha^{-1} for zero and high rates, respectively). In 1995, due to recovery of MT at all rates (1.30, 0.94, and 0.95 Mg ha^{-1} for low, medium, and high, respectively) the maximum reduction in MT DM was 50% for the high rate compared to the unsprayed control (2.0 Mg ha^{-1}). Most of the DM increase occurred from recovery of existing plants and not from seedling emergence. As had occurred in 1995, there was significant recovery of MT in 1996, but most of the recovery between 2 to 4 mo after spraying occurred at the low rate of glyphosate (4.0, 3.0, 0.80, and 0.40 Mg ha^{-1} for unsprayed, low, medium, and high, respectively). Reduction in MT DM at 4 mo after spraying in 1996 was 88 and 90% for the medium and high rates, respectively.

There was no effect of glyphosate on DM of CG or other grasses in the sward at 2 or 4 mo after spraying in 1995 (Fig. 5.2a,b) and 1996 (Fig. 5.3 a,b). There was a linear effect ($P=0.02$) of glyphosate rate on RPP DM at 2 mo after application in 1995 (1.7 and 0.81 Mg ha^{-1} for zero and high rates, respectively). This reduction was still evident at 4 mo after spraying. Rhizoma perennial peanut DM at the low rate 4 mo post spraying (2.30 Mg ha^{-1}) was higher than at 2 mo post spraying (1.60 Mg ha^{-1}) indicating some recovery of RPP. In contrast to what had occurred in 1995, RPP DM showed a cubic effect (P=0.04) at 2 and 4 mo post application in 1996. This was due to RPP DM at the low rate (1.20 Mg ha^{-1}) being slightly higher than at the zero rate (1.10 Mg ha^{-1}) 2 mo post application. Rhizoma perennial peanut DM at the medium rate (0.50 Mg ha^{-1}) was lower than at the high rate (0.70 Mg ha^{-1}). Similar effects were observed at 4 mo post application.

Triclopyr Effects on Dry Matter in 1995 and 1996

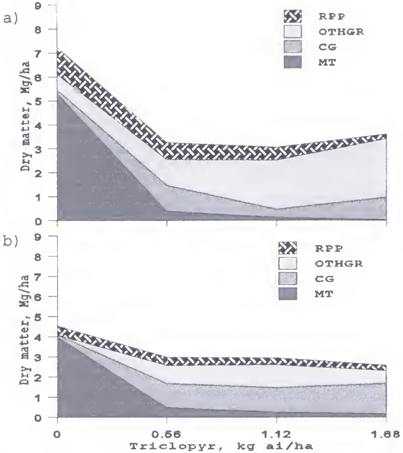
There was a quadratic effect on MT DM at 2 (P<0.01) and 4 (P=0.02) mo post spraying in 1995 (5.4 a,b). At 2 mo after spraying, MT DM decreased from 1.60 to 0.30 Mg ha^{-1} for zero and low rates, respectively, but there was no effect of increasing rate of triclopyr from low to high (avg. 0.30 Mg ha^{-1}). This represents an 81% reduction in MT DM, and unlike glyphosate treatments in 1995, this reduction represents the death of a large percentage of the target species. Similar effects were still present at 4 mo post spraying, with only slight recovery of MT evident at the low rate (0.30 vs. 0.68 Mg ha^{-1} at 2 and 4 mo post application, respectively). Medium and high rates of triclopyr at 4 mo showed little evidence of regrowth with close to 100% control. In 1996 (Fig. 5.5 a,b), there was a quadratic effect (P<0.01) of rate on MT DM at 2 mo and 4 mo after spraying. Low rate reduced MT DM by 92% (0.40 vs. 5.30 Mg



	2 month				4 month			
Contrasts†	MT	CG	OTHGR	RPP	MT	CG	OTHGR	RPP
TP-L	<0.01	<0.01	0.22	<0.01	<0.01	<0.01	0.60	<0.01
TP-Q	<0.01	0.41	0.06	0.06	0.02	0.24	<0.01	0.21
TP-C	0.16	0.26	0.77	0.34	0.98	0.29	0.34	0.65

†P values for triclopyr (TP) linear (TP-L) effect, TP quadratic (TP-Q) effect, and TP cubic (TP-C) effect.

Fig. 5.4 a,b. Effect of triclopyr (TP) rates on dry matter yield of Mexican tea (MT), cogongrass (CG), other grasses (OTHGR), and rhizoma perennial peanut (RPP) at (a) 2 and (b) 4 mo post application in 1995.



	2 month				4 month			
Con-trasts†	MT	CG	OTHGR	RPP	MT	CG	OTHGR	RPP
TP-L	<0.01	0.16	<0.01	<0.01	<0.01	0.01	0.05	0.35
TP-Q	<0.01	0.53	0.96	0.77	<0.01	0.24	0.01	0.98
TP-C	0.07	0.01	0.61	0.49	0.09	0.38	0.90	0.99

†P values for triclopyr (TP), TP linear (TP-L) effect, TP quadratic (TP-Q) effect, and TP cubic (TP-C) effect.

Fig. 5.5 a,b. Effect of triclopyr (TP) rates on dry matter yield of Mexican tea (MT), cogongrass (CG), other grasses (OTHGR), and rhizoma perennial peanut (RPP) at (a) 2 and (b) 4 mo post application in 1996.

ha^{-1} for low vs. zero rates, respectively), and MT DM varied little as rate increased from low to high (avg. 0.20 Mg ha^{-1}) at 2 mo after spraying. The average DM reduction occurring across triclopyr rates was 97%. Similar to 1995, there was only slight recovery of MT at the low rate (0.40 and 0.50 Mg ha^{-1}, at 2 and 4 mo post application, respectively).

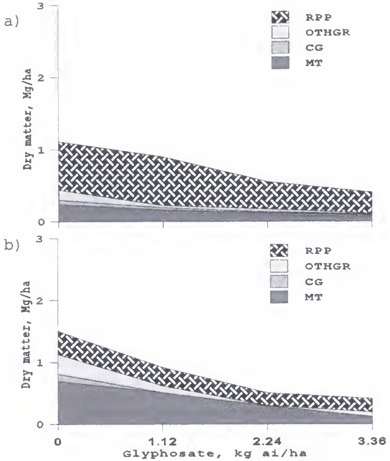
In 1995, RPP DM declined linearly ($P<0.01$) with increasing triclopyr rates at 2 mo post spraying, and there was a maximum DM reduction of 68% for the high rate (1.70 and 0.54 Mg ha^{-1} for the zero and high rates, respectively). At 4 mo post application, there was still a linear effect ($P<0.01$) of triclopyr rate on RPP DM (2.0 and 0.74 Mg ha^{-1} for zero and high rates, respectively). Some recovery of RPP DM occurred on triclopyr-treated plots between 2 and 4 mo post spraying. Averaged over the three rates, RPP DM was 0.60 and 0.90 Mg ha^{-1}, at 2 and 4 mo post application, respectively. Unlike 1995, in 1996 there was a linear decrease ($P<0.01$) in RPP DM with increasing rates of triclopyr at 2 mo (1.10 and 0.20 Mg ha^{-1} for zero and high rates, respectively), but not at 4 mo post spraying. At 4 mo post spraying there was no effect of triclopyr rates on RPP DM, and 0.30 Mg ha^{-1} was the average for low, medium, and high rates compared to 0.50 Mg ha^{-1} at the zero rate.

In 1995, DM of CG increased linearly ($P<0.01$) with increasing rates of triclopyr (1.10 and 3.50 Mg ha^{-1} for zero and high rates, respectively) at 2 mo after spraying. At 4 mo after spraying, similar linear effects ($P<0.01$) were observed (1.10 and 4.50 Mg ha^{-1} for zero and high rates, respectively). Enhanced growth of CG in treated plots may be due to reduced competition from broadleaf weeds, particularly MT. Triclopyr had no effect on other grasses at 2 mo post application, but at 4 mo there was a quadratic effect ($P<0.01$) of rates of triclopyr due to a decline in other grasses at the high rate of triclopyr. This was likely due to increased competition from CG. In contrast to what occurred in 1995, in 1996 there was a cubic effect ($P<0.01$) of triclopyr rate on CG DM and a linear effect($P<0.01$) on other grasses DM in 1996. Cogongrass DM increased as triclopyr rate increased from 0 to 0.56 kg ai ha^{-1}, decreased slightly with the medium rate and increased again at the high rate. Other grasses DM increased linearly ($P<0.01$) as triclopyr rate increased. At 4 mo post spraying, CG DM increased linearly as triclopyr rate increased. Other grasses DM increased when rate increased form zero to low, but it remained nearly constant thereafter (quadratic effect, $P<0.01$).

Regrowth and Total Seasonal Yield

Mexican tea regrowth (Fig. 5.6 a,b) during the 2 mo regrowth period after the 2 mo post spraying harvest declined linearly ($P<0.01$) with increasing rates of glyphosate, in 1995 (0.24 and 0.08 Mg ha^{-1}, for zero and high rates, respectively) and 1996 (0.70 and 0.10 Mg ha^{-1}, for zero and high rates, respectively). There was a linear decline ($P<0.01$) in regrowth of RPP with increasing rates of glyphosate in 1995 (0.70 and 0.30 Mg ha^{-1}, for the zero and high rates, respectively), and a trend ($P=0.08$) for a similar decline in RPP DM in 1996. Regrowth of CG and other grasses DM was not affected by glyphosate treatment in 1995 and 1996.

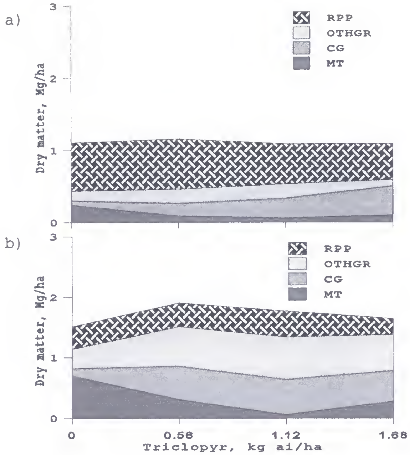
There was a quadratic effect ($P<0.01$) of triclopyr rate on regrowth of MT DM in 1995 and 1996. This was because there was a similar small amount of regrowth on treated plots regardless of herbicide rate (Fig. 5.7 a,b). This represented a 70% reduction in MT regrowth DM for treated plots relative to the zero rate for both years. Average MT regrowth DM for treated plots was 0.07 and 0.22 Mg ha^{-1} in 1995 and 1996, respectively. In 1995 and 1996, there was no effect of triclopyr on RPP regrowth DM, although in 1995 there was a trend ($P=0.09$) toward lower RPP regrowth with higher rates of triclopyr.



	1995				1996			
Con-trasts†	MT	CG	OTHGR	RPP	MT	CG	OTHGR	RPP
GP-L	<0.01	0.58	0.18	<0.01	<0.01	0.62	0.27	0.08
GP-Q	0.52	0.75	0.54	0.55	0.90	0.71	0.42	0.47
GP-C	0.77	0.88	0.59	0.17	0.89	0.86	0.94	0.66

†P values for glyphosate (GP) linear (GP-L) effect, GP quadratic (GP-Q) effect, and GP cubic (GP-C) effect.

Fig. 5.6 a,b. Effect of glyphosate (GP) rates on regrowth of Mexican tea (MT), cogongrass (CG), other grasses (OTHGR), and rhizoma perennial peanut (RPP) in (a) 1995 and (b)1996.



	1995				1996			
Contrasts†	MT	CG	OTHGR	RPP	MT	CG	OTHGR	RPP
TP-L	0.06	<0.01	0.60	0.09	<0.01	0.12	0.23	0.32
TP-Q	<0.01	0.93	0.16	0.52	0.01	0.12	0.20	0.19
TP-C	0.99	0.86	0.76	0.62	0.51	0.69	0.84	0.48

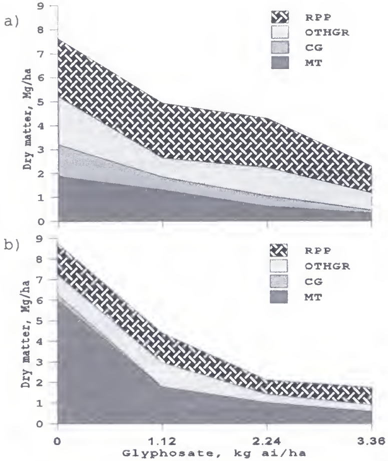
†P values for triclopyr (TP) linear (TP-L) effect TP quadratic (TP-Q) effect, and TP cubic (TP-C) effect.

Fig. 5.7 a,b. Effect of triclopyr (TP) rates on regrowth dry matter yield of Mexican tea (MT), cogongrass (CG), other grasses (OTHGR), and rhizoma perennial peanut (RPP) in (a) 1995 and (b)1996.

Total seasonal DM of MT declined linearly (P<0.01) with increasing rates of glyphosate (1.90 and 0.30 Mg ha^{-1} for zero and high rates, respectively) in 1995 (Fig. 5.8 a,b). In 1996, there was a quadratic effect (P<0.01) on MT DM, because of the higher levels of MT DM (6.0 Mg ha^{-1}) in control plots and the resultant large decline in MT DM with the first increment of glyphosate.

Total seasonal RPP DM decreased linearly (P<0.01) with increasingly glyphosate rate in 1995 (2.40 and 1.10 Mg ha^{-1}, for zero and high rate, respectively; Fig. 5.8 a,b). Rhizoma perennial peanut DM for low and medium glyphosate rates in 1995 were 2.30 and 2.0 Mg ha^{-1}, respectively, only slightly less than the control (quadratic trend, P=0.12). In 1996, there was a cubic effect (P=0.04) of glyphosate rate on RPP DM. Rhizoma peanut DM showed a slight increase as glyphosate rate increased from zero to 0.56 kg ai ha^{-1}, decreased at the medium rate, and increased again at the highest rate. Cogongrass and other grasses were not affected by glyphosate rates in 1995 and 1996.

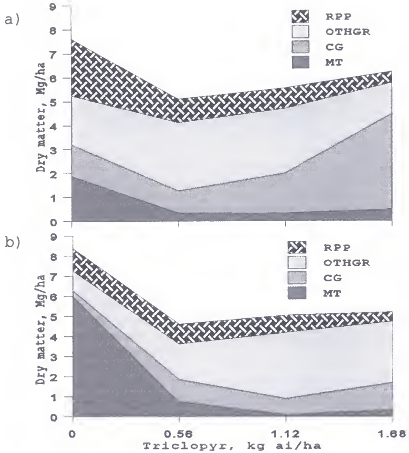
There was a quadratic effect (P<0.01) of triclopyr rate on seasonal MT DM in 1995 and 1996 (Fig. 5.9 a,b). This was due to similar responses among low, medium, and high rates of triclopyr, all of which were lower than the zero rate. This represented an 80 and 95% reduction in MT DM in 1995 and 1996, relative to the control. There was a linear



Con-trasts†	1995				1996			
	MT	CG	OTHGR	RPP	MT	CG	OTHGR	RPP
GP-L	<0.01	0.19	0.09	<0.01	<0.01	0.58	0.30	<0.01
GP-Q	0.51	0.71	0.42	0.12	<0.01	0.68	0.79	0.46
GP-C	0.61	0.76	0.21	0.57	0.11	0.85	0.52	0.04

†P values for glyphosate (GP) linear (GP-L) effect, GP quadratic (GP-Q) effect, and GP cubic (GP-C) effect.

Fig. 5.8 a,b. Effect of glyphosate (GP) rates on total seasonal dry matter yield of Mexican tea (MT), cogongrass (CG), other grasses, and rhizoma perennial peanut (RPP) in (a) 1995 and (b)1996.



	1995				1996			
Con-trasts†	MT	CG	OTHGR	RPP	MT	CG	OTHGR	RPP
TP-L	<0.01	<0.01	0.25	<0.01	<0.01	0.05	0.01	<0.01
TP-Q	0.01	0.04	0.02	0.13	<0.01	0.67	0.37	0.71
TP-C	0.20	0.88	0.85	0.51	0.06	0.18	0.32	0.37

†P values for triclopyr (TP) linear (TP-L) effect, TP quadratic (TP-Q) effect, and TP cubic (TP-C) effect.

Fig. 5.9 a,b. Effect of triclopyr (TP) rates on total seasonal dry matter yield of Mexican tea (MT), cogongrass (CG), other grasses (OTHGR), and rhizoma perennial peanut (RPP) in (a) 1995 and (b)1996.

decline(P<0.01) of RPP DM with increasing rates of triclopyr in 1995 (2.40 and 1.0 Mg ha^{-1} for zero and high rates, respectively) and in 1996 (1.50 and 0.50 Mg ha^{-1} for zero and high rates, respectively). This represented a reduction in RPP DM relative to the control of 41, 49, and 56% for low, medium, and high rates, respectively in 1995, and 33, 40, and 66%, respectively, in 1996. Total seasonal yield of CG increased at an increasing rate (quadratic; P=0.04) in 1995 and linearly (P=0.05) in 1996. Other grasses DM in 1995 was higher at the low and medium rates than for the control but lower at the high rate, mainly due to a large increase in CG at that rate. In 1996 other grasses DM increased linearly (P<0.01) as triclopyr rate increased. Averaged across rates, triclopyr treatments resulted in an increase in CG of 65 and 75% for 1995 and 1996, respectively and in other grasses of 13 and 150% for 1995 and 1996, respectively, due to less competition from MT and RPP.

Discussion

Glyphosate Effects on Dry Matter in 1995 and 1996

There was a linear decrease in MT DM with increasing rates of glyphosate at 2 mo post application in 1995 and at 4 mo in both years. The response was quadratic 2 mo in 1996. The quadratic response was due to highest reduction in MT DM occurring from zero to 1.12 kg ai ha^{-1}. In both years, recovery of MT was observed and was greater for the 1.12 kg ai ha^{-1} rate than for higher rates. Most of the recovery was observed on existing plants which suggest that MT was not killed completely by glyphosate. Campbell et al. (1991) noted that glyphosate rates of 1.8 kg ai ha^{-1} were effective in controlling a perennial forb, St. John's wort (Hypericum perforatum L.), but that this plant recovered when lower rates (0.9 kg ai ha^{-1}) were applied. Environmental factors such as rainfall in the summer may have influenced herbicide efficacy. Rainfall occurred the afternoon after herbicide application in 1995, but there was no rain on the day herbicides were sprayed in 1996. This probably explains why the low rate of glyphosate was much more effective at 2 mo post application in 1996 than 1995 (Fig. 5.3 a,b). Lodge et al. (1994) noted that rainfall before and after herbicide application is an important factor determining the rate of herbicide recycling within the plant, the movement of herbicide to the root zone, and loss of herbicide by runoff. The recovery of MT observed at all rates suggest that more than a single application will be required to minimize MT invasion in RPP-mixed grass swards.

Glyphosate application had no effect on CG or other grasses in 1995 and 1996. Gaffney (1996) reported that applications of glyphosate in the fall were more effective (80%) than summer applications (40% control) for control of CG. He attributed this to better translocation to below ground storage. Similar effects of glyphosate was observed on johnsongrass (Sorghum halepense L.), a perennial rhizomatous weedy grass (Lodge et al., 1994). The effect of glyphosate applications in the fall on CG, grass, and RPP components should be assessed.

Rhizoma perennial peanut DM declined with increasing rates of glyphosate at 2 and 4 mo post application in 1995 (Fig. 5.2), while a cubic effect (Fig. 5.3 a,b) was observed for 2 and 4 mo post application in 1996. Argel and Valerio (1992) reported similar reductions in DM of A. pintoi to single applications of a broad spectrum herbicide (paraquat). The magnitude in reductions in herbage yield has important implications for the choice of herbicides and needs to be balanced against the likely loss due to weed competition. Johnson et al. (1994) noted that RPP production is reduced under high levels of shading, and this should be taken into consideration. The increase in RPP DM observed at 4 mo post application indicate recovery of RPP at the 1.12 kg ai ha^{-1} rate. Although MT control at the low glyphosate rate was not as effective as higher rates, it is possible that a single application of glyphosate in early spring, when MT is not as mature, may give better control at lower rates. Also this will give enough time to RPP to recover from the damage for summer grazing or hay harvest. Follow up studies are necessary to evaluate spring applications and to assess the long term effect of glyphosate on RPP.

Triclopyr Effects on Dry Matter in 1995 and 1996

In both years triclopyr applications regardless of rate were equally effective in reducing MT DM (Figs. 5.4 a,b and 5.5 a,b). Similar responses were observed for regrowth MT DM. This indicates that there was no advantage to increasing rates of the triclopyr for control of MT. Triclopyr was more effective in reducing MT compared to glyphosate because, even at the low triclopyr rate (0.56 kg ai ha^{-1}), only a minimal recovery of MT was evident relative to the zero rate. Medium and high rates showed little regrowth with close to a 100% control for the remaining of the growing season. The long term effectiveness of a single 0.56 kg ai ha^{-1} application of triclopyr on MT is not known. Studies with perennial broadleaf weed species have shown that more than one application of triclopyr is required to reduce infestations to an acceptable level (Campbell et al., 1991; Kalmbacher and Eger, 1994). In field plantings of RPP-mixed grass, regrowth of MT has been observed the year following triclopyr applications (M.J. Williams, personal communication). Follow up studies should consider long-term efficacy of triclopyr on MT populations.

Triclopyr stimulated CG and grass infestation in both years (Figs. 5.4 a,b and 5.5 a,b) due to a reduction in competition from MT and possibly RPP. This may be desirable if the grasses present are ones that will be utilized by grazing animals, but it is not a desirable effect when CG present. Cogongrass proliferates by means of rhizomes, and increases in its proportion in the sward may affect RPP survival by increased underground competition and shading. Effect of competition from CG and other grasses on RPP DM were not quantified, but previous work has shown that RPP production is reduced under high levels of shading (Johnson et al., 1994). To reduce increased competition from grass with RPP when using triclopyr, grazing may be useful to manipulate grass-RPP swards. There are no grazing restrictions on the rates of triclopyr tested. Caution should be exercised, however, in the use of triclopyr if CG is major weed component of the sward, because cattle generally will not graze CG.

Rhizoma peanut DM at 2 and 4 mo after spraying decreased with increasing rates of triclopyr in 1995 (Fig. 5.4 a,b). This effect was only observed at 2 mo post application in 1996. Some recovery of RPP DM occurred between 2 and 4 mo post application. Evans et al. (1989)

observed that phenoxy herbicides can cause yield reductions of up to 62% in subterranean clover (Trifolium subterraneum L.). Yield reductions in clover have been observed to vary from 16 to 71% between site and year (Dear et al., 1995). Similar variation in year was observed in this study. The lower RPP DM observed at the 4 mo post application in 1996 may be due to lower rainfall (274 vs. 67 mm, for October 1995 and 1996, respectively) that growing season. There was only a slight reduction in RPP DM regrowth in 1995 and no effect of triclopyr on RPP DM regrowth in 1996 (Fig. 5.7 a,b), indicating that RPP is fairly tolerant of a single application of triclopyr even at the 1.68 kg ai ha^{-1} rate.

Summary and Conclusions

These results show that within the range of herbicides tested both triclopyr and glyphosate can be useful in weed-infested RPP stands but that glyphosate at the rates tested was not as effective as triclopyr in controlling MT. Triclopyr effectively reduced MT DM in both years by more than 90%. Because these rates resulted in significant substitution of grasses for MT, triclopyr may not be useful when undesirable grasses such as CG are present. Because herbicide rates that were more effective against weeds also decreased RPP DM, their use must be weighed against potential losses in long-term productivity of RPP. Because of the difficulty and the high cost of completely eliminating weeds with herbicides, periodically suppressing the weed population an acceptable level may be necessary.

It is concluded that single applications of triclopyr at 0.56 kg ai ha^{-1} can be used effectively to reduce MT and manipulate the botanical composition of RPP-mixed grass swards. Glyphosate at 2.24 kg ai ha^{-1} can be used strategically to reduce MT, but additional information is needed on its effects on CG and other grasses.

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BIOGRAPHICAL SKETCH

Elide Valencia was born January 24, 1954 in Yo Creek Village, Belize. He graduated from high school in 1972, and ventured with his parents in sugar cane farming for the next two years. At the age of 20, he initiated a career in agriculture at the Panamerican School of Agriculture (Zamorano, Honduras), and received an associate degree "Agronomo" in 1977.

From 1978 to 1983, Elide worked in Belize as an Extension Agent. In 1984, he enrolled at Louisiana State University, and received his bachelor's degree in 1986. Upon his return to Belize, he directed the national forage research program of the Ministry of Agriculture for five years.

In 1991, Elide was granted an academic fellowship to conduct research with forage Arachis in Puerto Rico. He initiated a Master's program in Agronomy at the University of Puerto Rico, that same year, and graduated in 1993. Currently, he is specializing in grassland management, and is a candidate for the degree of Doctor of Philosophy.

Elide is a member of the American Society of Agronomy, American Forage Grassland Council, Caribbean Foods Crop Society, and Gamma Sigma Delta, the honor Society of Agriculture.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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